ALYTICAL
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OF
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ANALYTICAL ESSAY

ON THE

CONSTRUCTION

OF

MACHINES:

Translated from the French

OF

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PREFATORY ADDRESS.

THE state of perfection which the manufacturing Arts have attained in this country may be traced to the general Advancement of Science which has distinguished the present Age. Hence, we must look for a continuance of improvement by a proportionate progress in scientific Knowledge; and every attempt which has that object in view, and is executed with adequate ability, has a rightful claim to the grateful sense of the age and country in which it has been produced.

This observation might be thought sufficient to justify the introduction of any foreign work of general Utility to the attention of the English Nation, by cloathing it in the English Language. But the Editor presumes to take an higher ground in favour of this Volume from the great Utility of its subject and the Novelty of its Execution. An Elementary work that brings a mass of important prac-

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tical information within the circle of early studies; that may be considered as a Grammar in the Science of Mechanics; is so arranged as to be perfectly intelligible to that invaluable class of Society, the practical Artisans, and at the same time may be a useful volume of reference to the more learned Classes, cannot but be considered as a useful and consequently an acceptable addition to the British Library; as it will transmit to this country the honour which the Author has established in his own.

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ANALYTICAL ESSAY

ON THE

CONSTRUCTION OF MACHINES.

THE nature of the mechanical movements which occur in the construction of machines, may be classed in three divisions, viz. rectilinear, circular, and those which are regulated by other given curves, and the subjects of either of these classes will again arrange themselves, under the distinct heads of direct and alternate motion.

Fifteen different arrangements may therefore be made of those motions by combining them in pairs, or twenty-one different arrangements, by combining each with each. The object of all mechanical arrangements is either to communicate some of those motions, or, by combining and transposing them to produce any required conversion of them.

The Synoptical table (Plate 13) affords a perspicuous display of the best examples of these several motions. It is composed of twenty-one equal horizontal ranges of square compartments, each of which contains one example; each range is distinguished by numeral figures, and each vertical column by Roman capitals, the intersection of two columns or the situation of any given example is therefore indicated by a letter with an affixed numeral, i e, the distinguishing letter of the vertical column and the numeral of the horizontal range. The open spaces which occur in some parts of the table from the greater abundance of examples in other of the ranges, are evidently unavoidable from the nature of the arrangement, they may however not improperly be considered as

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reserved to register those future discoveries and inventions which the researches of practical and scientific men may be expected everywhere to produce.

In order to confine the table of contents within convenient limits, and avoid the disagreable effect of frequent extensive ranges of open spaces, whenever the number of examples occurring of one class, have exceeded twenty, the remaining subjects have been arranged in a supplementary range, immediately below the first, and distinguished by the same numeral figure with the addition of a line, as in the ninth range, where the supplementary range (which became necessary from the number of examples) is marked 9′; And whenever the conversion of one given movement to another is not immediate, but must be effected by a preparatory conversion to some other movement then a single line of explanatory description is introduced in place of the horizontal range of examples, as in range 2, which should contain examples of alternate rectilinear motion, as produced by conversion from direct rectilinear motion: here the required conversion is not immediate, but is to be effected by the preparatory conversion shewn in the 3rd range, which the line of explanatory description accordingly refers to.

To avoid useless repetition, the 1st compartment of an horizontal range is sometimes occupied by a concise reference to movements which are to be found in other parts of the table, and which might also have been placed in that column, either in the state in which they are found by that reference, or modified by the intervention of another, as in column 4, where direct rectilinear motion is required to be converted into alternate circular motion: here the first compartment of the range informs us that if the given rectilinear motion be first converted into direct circular motion by some of the methods exhibited in the 3rd range, reference from thence to the 9th range will furnish the required conversion.

Each horizontal range of examples, furnishes the subjects of description of a section of the work, in which the object of each combination is explained, with the general solution of the problems analogous to the conversion required; The particular modes of execution with which we are acquainted are shewn by reference to the sources of information, and considerations are added on

the value of such means, and the various practical applications which may have been made of them.

The subjects of the general table or index plate (Plate 13.) are also drawn to a larger scale, in which each subject has the literal and numeral characters prefixed which point out its situation in the index plate, as for instance, the 1st figure of plate 1, is distinguished in that plate, and referred to from the index plate by the designation B 1, which explains its situation in the index plate to be the intersection of the 1st horizontal range with the vertical column B. Eight of these subjects are arranged in each plate, and each has its respective letters of reference for the description. We have also been obliged to introduce some auxiliary examples in a distinct plate (No. 12.) which do not arrange themselves in the index plate.

SECTION. I.

To convert direct and equable rectilinear motion, or the velocity of which is variable according to a given law, into direct rectilinear motion of velocity similar to that of the moving power, either equable, or variable by a given law, and in the same, or in a different direction.

THE only first movers the mechanical action of which can be considered as being direct and rectilinear, are 1st the Air—either by its motion, its gravity, its elasticity, or its rapid expansive force. 2d. Water—either by its motion, its gravity, its re-action, or by the expansive power of steam. And 3d. Gunpowder—either by its explosive force, or its re-action, as in the instance of the common rocket*.

* Examples of the instantaneous expansion of air, by the combustion of gunpowder or other combustible substances, applied as first movers, may be found in the Repertory of Arts and Manufactures, vol. i. p. 154; and in vol. vi. p. 100, a memoir on the subject by Bramah. In the works of Jean de Haute Fenille, printed at Paris 1694, is also a memoir under the title "Pendulle perpetuelle;—la maniere d'elever l'eau par le moyen de la poudre á canon, &c." We find the Academy of Sciences engaged at that time in adapting this power to raising heavy bodies. And the author has proposed an hydraulic telegraph, in which he believes is the earliest idea of communicating the action of a power to

An endless rope, moving about two fixed pullies may exemplify rectilinear motion, which is in fact, but direct motion in a circle whose radius is infinite. The progress of a body in a direct line between two given points, either by its own motive powers, or by the action of any first mover, is a more distinct example of rectilinear motion. The arrangements of the art of marine rigging afford many instances, and all those engines which act by means either of simple or combined pullies.

The arrangement B 1, and C 1, of plate 1, exhibit the most familiar instances of this proposition :—D 1, E 1, F 1, G 1, H1, K 1, are examples of parallel motion.

(A 1.) Index plate. (Plate 13.)

If circular motion be produced from rectilinear by the methods exhibited in the 3rd range, different examples of the required conversion may be found in that range.

(B 1.) (B 1, 2nd figure.) Plan and Elevation—Plate 1.

The points a and b are reciprocally required to traverse the respective spaces a b and c d with the same given velocity.

A general solution of this problem may be afforded by a simple pulley e, (fig. B 1,) or by two such pullies, if the given points are required to move in different planes (B 1. 2nd fig.)

(C 1.)

Problem 2. This is a repetition of the last problem, but with the condition that the distance traversed by c, is less than that of a, in a given ratio. A general solution of this problem is afforded by the combinations of pullies, which are usually adopted for the purposes of lifting heavy masses. These expedients are too well known to need minute explanation, but many examples worthy the attention of mechanics may be found among the machines approved

great distances by means of long tubes filled with water. A report by Berthollet and Carnot, upon a machine invented by Messrs. Niepce, will be found in the Memoirs of the first class of the Institute for 1817, page 146, these gentlemen term their machine "Pyreolophore," and apply the instantaneous expansion of air by combustion, as a first mover.

Applications of the pressure of water or of the atmosphere, as first movers, may be seen in "Les Annales des Arts et Manufactures," vol. xiii. page 209, by O'Reylli. A description of the engine of Schemnitz; the improvements proposed in it by Boswell; and a description of Goodwyn's machine.

by the Academy of Sciences; in the work of Sabaglia; and in all those authors who have written on the art of rigging maritime vessels.

(D 1.)

Problem.—To move a line continually parallel to itself. This motion is familiar to us in its applications to the common parallel rule used in geometrical drawing *.

(E 1.)

This is another application to a more commodious construction of the parallel rule: some useful applications of it have also been made by M. Ramsden †.

(F 1.)

The foregoing examples are in general not well adapted to works of considerable size, or where great accuracy is required. In our cotton spinning machinery we find however a very elegant and satisfactory specimen of a parallel motion: In this machine a platform which carries the spindles, and is from 18 to 27 feet in length, is required to traverse over a space of about five feet, and to retain in its path an accurate parallelism. The most costly and complicated means had been exhausted to effect this, when it was at length accomplished in a nanner at once so simple and correct as exceeded all that could have been expected. In the figures, B represents the carriage or platform running on four wheels a a a a, upon this carriage is placed a set of spindles, which receive their rotatory motion by the means shewn at G 8 of the table; d is the point to which the moving power is applied. The required constant parallelism of this machine seems extremely difficult to effect, from its considerable length, it is nevertheless obtained in a very perfect manner, by means of two cords n m p q, and r s t u, the first of these n m p q passes over two pullies s m, and the ends n q, are fixed. The second cord r s t u, also passes over two pullies, placed respectively over those already mentioned, and its ends r and u, are also fixed. It is necessary that the attaching points u q and n r, of the

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* See the work of James Leupold, entitled "Theatre de l'Arithmetique et de la Geometrie," 1727, plate xii. fig. 4.

† See the same work, plate xii. fig. 6.

two cords should be so situated as to stretch the cords perfectly parallel to each other, and with equal tension; and the carriage B, should be placed at right angles to them. These arrangements are easily practicable, and the effect is as perfect as can be conceived.

(G 1.)

A solution of this problem will also be obtained by the motion of a ruler a b, which runs on two fluted cylindric wheels or rollers c and d, placed near to its ends. It is necessary that these rollers should be precisely of equal diameter, and be so placed that their faces shall be perfectly parallel. This instrument preserves its parallelism merely by the friction produced by its own weight on the surface on which it rolls: but in the application of this movement to machines of considerable power, as in the instance of that which is used in boring artillery, it is necessary for the rollers to be deeply indented, for the purpose of engaging in hooks, which are fixed to a massive frame. To this ruler is sometimes added a dial, on which its progress is indicated, so that parallel lines may be described at any required distances.

(H 1.)

Let A be a wedge which is at liberty to slide longitudinally between four upright pillars c d e f, while a second wedge B, is so confined to the pillars by projecting pins, or friction rollers, that it is at liberty to move in a vertical direction only. It is evident that if under this arrangement the wedge A receives a motion in the direction f d, the upper wedge will be gradually raised, and the side n m, will move continually parallel to itself: we find this arrangement of wedges frequently applied to useful purposes, among others, to the pedals of musical instruments; but it appears capable of more extensive and useful application. M. De Bettancourt adopted it in England with complete success, for the purpose of raising the lower cylinder of a flatting engine; and he conceives that strait lines might be divided by this means, with as much accuracy as is now obtained with respect to circles by means of the present dividing plate. If we imagine the moving power to act constantly in the direction f d, of the base a b of the lower wedge, and that an arm or ruler l p, situated at right angles to the inclined plane c b, and having friction rollers at the extremity l, it will rest on the

inclined plane, and the ruler will slide between the two projections o and q. The inclination of the plane being arbitrary, it is evident that a direct rectilinear motion may produce a similar motion in a given angular direction with it, and the velocity of the first will be to that of the second, as radius is to the sine c b a. If the angle c b a be reduced to o, the rule or bar l p, will remain immoveable. This will be the case when the original rectilinear motion is converted into a rectilinear motion at right angles to it. These results are obtained by the help of the second wedge B, as already described; and if a third be added, which shall be attached to the second, both the direction of the movement and the relative velocities may be changed at pleasure. The line c b, may also be curved at pleasure, in which case the direct rectilinear motion will produce an alternate rectilinear motion, and the arrangement would be classed among those of Section II.

(I 1.)

Is the Hydraulic Ram of Montgolfier. A description of this engine may be found in the Repertory of Arts, volume 9; in the Journal de l'Ecole Polytechnique, volume 14; in the Journal des Mines, numbers 48, 64 and 66; in the Journal de Physique of February 1798; in the Bulletin de la Societé d'Encouragement, Number 19; Number 61, of the same work for July 1809, also contains an article on some improvements of the Hydraulic Ram.

A current or fall of water which we have considered as a first mover, acting with an uniform velocity and directly rectilinear, produces an alternate movement in a valve, and with the addition of an air vessel will afford a continued jet of water; and which we have also considered a direct rectilinear motion.

(K 1.)

This is another method of producing a motion which will preserve a constant parallelism: it is frequently used in the drawing instrument familiarly known by the name of parallel ruler, and may be seen in other applications in Leupold's Theatre de l'Arithmetique et de la Geometrie, fig. 5, plate 12. Parallel rulers on this construction are frequently introduced in cases of mathematical drawing instruments.

(L 1.)

A B is a flat bar or ruler, having a longitudinal passage cut through it from n to m. A small fixed cylinder c, is made to enter this passage without having any motion through it. C D is a bar which is allowed to slide easily between the two small clips p and q; and it also carries an upright arm E F, from some part of which at any distance from the bar C D there rises another small cylinder a, which also enters the longitudinal passage n m of the bar A B, but on the opposite side to the first mentioned cylinder c, and so that they do not come in contact with each other when the bars are in motion.

If the bar A B be made to move so that its end A shall take the direction of the right angle A G parallel to the bar C D, the point a, will in the same time traverse the right line a b.

It will be seen thus, that by the direct or alternate rectilinear motion of the point A, we may communicate to the bar C D a motion of the same kind, with a velocity of any required ratio, or even inversely, by arranging the cylinder a in the arm E F, in a suitable manner.

SECTION II.

To convert a given direct and equable rectilinear motion, or the volocity of which varies by a given law, into alternate rectilinear motion of velocity similar to that of the moving power, either equable or variable by a given law; and in the same or in different directions.

THE given rectilinear motion will be converted into circular, by the methods shewn in Section III.; and the examples of Section VII, may then be taken as examples of the required conversion.

Having considered a fall of water as an uniform rectilinear motion, if we imagine a vessel which is alternately filled with the water, and emptied of it by means of a syphon, a float enclosed in the vessel will rise and fall alternately. This mover may be seen in a work entitled "Utilissimo trattato dell' Aque correnti, &c." dal Cavalier Carlo Fontana. Rome 1696.

An application of it as a mover, has been made by Messrs. Bossu and Solage, in a model of a corn mill deposited in the Repository of Machines: but in this instance, instead of using a syphon to empty the vessel, the valves of supply and exit are opened by the motion of the float-rods. We are not aware of the reasons which determined those distinguished machinists to convert the alternate rectilinear movement of the float-rod into an alternate circular motion; and thence to a direct circular motion, rather than avoid the use of an useless intermediate movement, which so materially lessens the power of the engine *.

The steam engine, in which steam may also be considered as a power constantly acting in a rectilinear direction, and producing the alternate movement of the piston. Hydraulic pumps, such as are some of those used in the Hungarian mines, in which a column of water acts on a similar principle, and produces the same effect as steam in the steam engine. Those in which the sudden expansion of air by a rapid combustion, is used as a first mover. All these machines should be classed in this division of our work, although not perhaps in a direct manner. But as the changing the direct rectilinear motion of the moving power into the alternate rectilinear motion of the piston, frequently involves considerable complexity of means, we consider such instances rather as particular machines, than those simple elementary transformations which it is our immediate business to describe; and therefore we have deemed it sufficient to mention them.

The alternated movements exhibited in all bodies which are exposed to considerable changes of temperature, and more particularly the metals, may be ranked among the most powerful first movers. It frequently counteracts the intention of the mechanical artist, and requires the exertion of all his patience and

* The motion of a float is used in the boilers of steam engines, or in reservoirs, to maintain the level of the water within certain limits.——L'Architecture Hydraulique of M. De Prony, vol. 2, contains the description of a method of regulating the velocity of steam engines by means of a float furnished with a syphon, invented by M. De Bettancourt.

A description of an instrument invented by M. Solomani, for the purpose of preserving a given temperature in a receiver of water by means of an aréometer, which acts as the float, may be seen in L'art du distillateur des eaux-de-vie et des esprits, par M. Le Normand.

ability: his ingenuity when thus excited, however, devises the means not merely of extrication from the difficulties of the subject, but even in many cases converts them to his advantage. Remarkable instances may be traced in the contrivances adopted to neutralize the action of this mover in many of our horological machines; and the inconceivable precision obtained in the admeasurement of trigonometrical bases, by means of the metallic rods of M. Borda *. Among the instruments whose action depends on this property of expansion by encreased temperature, the thermometer of M. Brequet should be eminently distinguished. This alternate movement has been turned to useful account in regulating the draught of furnaces. A very elegant application of it has also been made by M. Molard, to the adjustment of two walls in one of the galleries of the Repository of Machines †.

(A 2.)

The oscillating column of M. Mannoury d'Ectot.

This machine resolves itself into two cylindrical tubes A and B, placed vertically, one immediately above the other; they are separated from each other by a small interval. The upper extremity of the tube A is closed by a plate, in which is a circular aperture d d, corresponding with a similar aperture in the tube B. C is a circular plate or diaphragm of smaller diameter than the aperture d d, and is placed a little below it. The action of the machine is thus:—The tube A being constantly supplied with water by a convenient reservoir, it will escape by the annular opening formed between the circular aperture d d, and the diaphragm C, and with the velocity proper to a column of water of uniform altitude. The annular aperture by which the water escapes encreases the usual contraction of the spouting fluid, and forms a conical portion of water: the apex of which, by a due adjustment of its distance from the tube B, must be made to reach a little way within it.

A conical portion of the fluid will remain stationary upon the diaphragm.

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* All the works on clock and watch-making contains examples of such arrangements.—Delambre. Base du system metrique.—Bulletin de la societé d'encouragoment, No. 48, June, 1808.

† Borgnis. Traité du mouvement des fardeaux.

The water rushes into the tube B, and if it be cylindrical will rise in it to a height equal to one third more than the altitude of the column in the tube A, but if it be conical the altitudes will encrease with the convergency of the cone. When it has reached its maximum of elevation, it descends, passes into the stationary portion f, and causes the running portion of the fluid to diverge and to project a paraboloidic sheet, through the separating interval of the two tubes until the tube B is entirely empty. The jets of water recover their original action; the contraction of the spouting portion of the water again takes place; and the same process is recommenced. This alternate movement is found to take place in equal times.

The noble inventor expects to apply this alternate rectilinear motion of water to useful purposes as a mover, and to render the engine itself preferable to a great number of those generally used for the purpose of raising water. A work descriptive of this nobleman's ingenious inventions is expected shortly to make its appearance.

M. Carnot, in his report to the Institute of the 28th December, 1812, upon the different hydraulic machines presented by M. Mannoury, states the general problem proposed by that gentleman to be—" From a given fall of water to elevate a portion of it above the reservoir by means of a machine, all the parts of which are absolutely fixed; and which, consequently, does not comprehend or require either levers, wheels, pistons, valves, or any other moving parts of whatever description."

M. Carnot explains the entire novelty of this proposition, and gives an account of the principal methods which have been successfully adopted by the author for its accomplishment: speaking of the oscillating column he says—" Of these methods, this appears to us to possess the most novelty, because we are not acquainted with any facts which could have suggested the fundamental idea." He explains the phenomenæ by reference to the principles of the forces of activity of bodies in motion, and closes his report with a well-merited eulogium on the intelligence and learning of the noble author.

SECTION III.

To convert a given direct, and equable rectilinear motion, or the velocity of which varies by a given law, into direct circular motion, of velocity similar to that of the moving power, either equable or variable by a given law, and in the same or in different directions.

THE re-acting engine of Segner gives a direct solution of the problem; and Mour's centrifugal machine, noticed by Euler, in the Memoirs of the Academy of Berlin, for the year 1751, gives a solution of the inverse problem; both these, therefore, class themselves in this Section.

(A 3.)

A cylinder having a motion on its axis, and a rope winding on its surface, gives a general solution of this, and the inverse problem. The arrangement is sufficiently familiar to render a more detailed description unnecessary.

(B 3.)

The cord used in the preceding movement is here superseded by an endless chain furnished with projecting teeth, which engage in a toothed wheel, affixed to the end of the cylinder.

(C 3.)

A NUT AND SCREW.

If the nut of a screw be fixed, and the screw be turned within it, the screw will have a motion which is composed of its own rotation on its axis, and the conversion to direct rectilinear motion. Thus it is used in the arts to penetrate hard substances—to draw or force them together—to lift heavy burthens—and in some of the tools of watchmaking, as drills. The axis of the drill is so placed that its ends are supported by two screws, the nuts of which are confined or held between the puppets of a lathe. The two screws being turned by this means in opposite directions, communicate to the drill the required rectilinear motion. Another method, which is much to be preferred, is to support the drill by two steel cylinders which pass through the puppets of the lathe, and close to

these are placed two screws, the nuts of which are also held by the same puppets. The heads of the screws are in this case of sufficient size to press against the ends of the two cylinders which support the axis of the drill; and when turned in opposite directions gives to the drill the required motion, and in a more steady manner than was afforded by the preceding method.

If the screw be turned without being suffered to change its place, the nut must not be allowed to turn, but to have liberty to move in the longitudinal direction of the screw, and in this case the circular and rectilinear movements are divided, and a direct solution of the problem is obtained: the circular movement being converted into rectilinear. A rotatory motion of the screw may also be produced by giving the nut a rectilinear motion, but the friction of this motion is so considerable that it is seldom practised.

It is frequently required to hold a screw and its nut together, so that no change of their relative positions may take place by accident, carelessness of workmen, or by any violent motion or shock which might be produced by the machine; this is effected in a very simple manner by means of a second nut, which screws close upon that which is required to be fixed; the first nut is thus continually pressed forward in the longitudinal direction of the screw by the second nut; and the friction between the first nut and the screw, being as already observed, very great, the action exerted is not sufficient to overcome the resistance; the re-action of the nut, which is pressed upon, operates upon the tightening nut; and the resistance encreasing with the pressure, they both become fixed.

The screw is one of the mechanical powers of the most general use in the arts; there are few in which it is not rendered useful, and it varies its character of usefulness: sometimes having relation to the mechanical composition of the instrument, sometimes to the purpose for which it is to be used.

An arrangement of two screws placed parallel to each other is frequently used to produce the parallel motion of a plane of considerable length.

Presses for different purposes are constructed on this principle. In the 4th volume of the machines approved by the Academy of Sciences we find the application of the screw to the construction of a press, proposed by M. Jacques Le Maire: the editor of that work observes, that this method of applying the

screw is extremely ingenious, that it would be found useful in a great diversity of ways, and will produce the most striking effects. He states M. Le Chevalier De Ville to be the inventor, who employed it for the purpose of forcing barricádoes: and has shewn the method of application in his treatise entitled—" Traité de Fortifications de l'attaque et de la defense des places," page 228, plate 37. Printed at Lyons 1629. Descriptions of it will also be found in other works.

If two threads be cut on the same cylinder in opposite directions, they will move two nuts at the same time, also in opposite directions.

(D 3.)

A method of converting circular into rectilinear motion with an extremely low velocity has been discovered by M. Prony. It is by means of this contrivance that we are enabled to avoid the necessity of using screws of an unusually fine thread, to procure a slow adjusting motion. The disadvantages arising from the use of such screws were formerly very great; the rapid wear and consequent inaccuracy of the usual micrometers was an instance of the ill consequences produced by that circumstance. It is also capable of many other practical and useful applications. The original idea of the inventor is extremely simple and elegant.

A B is an axis or spindle divided into three portions a b, c d, e f. The two screws ab, e f, are of the same thread: they pass through the two fixed supports C D, in each of which there is a nut; the spindle has an horizontal motion, and at each revolution of the screw moves over a space equal to one of its threads; the portion c d, is formed into another screw, the thread of which may either be a little finer or a little coarser than that of the screws a b, e f, and the difference may be small at pleasure. A nut M is introduced, in which the threads of a micrometer are fixed: this nut being checked by the block E F, is not at liberty to turn with the spindle A B, which it would otherwise do: but at each revolution of the spindle moves a space equal to one of its own threads, its rate of motion is therefore compounded of the actual and relative advance of the spindle A B: so that it really moves but the amount of the difference between those motions.

This is M. Prony's simple and ingenious solution of this problem.

In practice it will be found difficult to make the two screws a b, and e f, so accurately alike, that there shall be no resistance in the nuts: one of these might however be omitted, that portion of the spindle being in that case made plain or cylindrical.

(E 3.)

A spiral winding about a cylinder, and exposed to a current of air or water, will convert the rectilinear motion of those fluids into a circular motion. The spiral of Archimedes may be considered as the inverse of this problem *.

The process of constructing this spiral may be found in the collection of machines approved by the Academy of Sciences of Paris, vol 7, No. 479. This method is there proposed by M. Dubost, for the construction of a mill upon the Rhone. In volume v, No. 338, of the same work, M. Du Quet proposed it for the construction of a machine intended to raise sunken vessels. It is also applied to the operation of turning the common jack used in our kitchens, by means of the current of air which continually passes through the chimney; and to other machines for the purposes of the log instrument, for measuring the progress of maritime vessels †.

(F 3.)

Vertical water wheels, with plane floats.

(G 3.)

Horizontal water wheels, with curved floats.

(H 3.)

Over-shot water wheels.

M. Borda in a memoir on water wheels, printed in the Memoirs of the Academy

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* The theory of the screw of Archimedes may be seen in L'Hydrodynamique de Daniel Bernoulli. A memoir by Pitot, in the memoirs of the Academy of Sciences for 1736;—another by Euler, in the memoirs of the Imperial Academy of Petersburgh, vol. v. for the year 1754.—A work by P. Belgrado, entitled "Theoria cochleæ Archimedis; ab Observationibus, Experimentis et Analyticis rationibus ducta, 1767."—The premium of the Berlin Academy in 1765, adjudged to M. Jean Frederic Honnerol;—and the work of Paucton, on the Theory of the Archimedian screw.

† See Theatrum Machinarum de Leupold, vol. i. plate 51. Theatrum machinarum novum, &c. per Gregorium Andream Bocklerum, 1662, fig. 81, 82.—Designs for Wind and Water Mills, &c. by Jacques de Strada, published by Octave de Strada. Frankfort, 1617, fig. 49.

of Sciences of 1767, has given many important calculations on the subject, shewing the most effective mode of applying the moving powers to such wheels, and their effects under different circumstances; and closes his memoir with the following reflections on the practical application of his researches.

OF VERTICAL WHEELS WITH PLANE AND INCLINED FLOATS.

Such wheels are capable of producing the half of the maximum effect, if the floats moving in their channel exactly occupy the whole passage, allowing no particle of the water to escape without communicating to them its excess of velocity; but it is necessary to allow a small space sufficient to avoid the collission of the floats with the bottom and sides of the channel; although this at the same time allows a portion of water to escape which has not exerted any action. It is difficult to determine the diminution of effect produced from this cause, since it depends more or less on accuracy of workmanship; but it seldom happens that the practical effect of such wheels is more than three-eighths of the maximum effect, although in theory it may be considered equal to one half.

OF HORIZONTAL WHEELS WITH PLANE FLOATS.

These wheels do not lose by a great deal so much of the action of the water as the preceding ones, and should consequently be preferred where the quantity of the fall, or other circumstances will allow the equal choice. They have also the advantage of being susceptible of a considerable encrease of their velocity according to its required action on the machinery to which it is applied, instead of the constant velocity of one half of that of the current, which suits the maximum effect of vertical wheels.

OF HORIZONTAL WHEELS WITH CURVED FLOATS.

These wheels have not the advantages over those of the preceding form which theory assigns them: because in practice it is nearly impossible that the whole of the water should enter the curves—conform to their figure—and leave them

in an horizontal direction: all which circumstances must take place for a maximum effect to be produced. Notwithstanding these, and other defects which it would be tedious to detail, these wheels are always of superior effect to horizontal wheels with plane floats; and in cases where a copious or sufficient fall of water can be obtained, they are certainly preferable to the usual vertical wheels in a still greater degree. For example—I am persuaded, it is perfectly practicable to construct an horizontal wheel with curved floats; the effect of which, with respect to a vertical wheel of the common construction, shall be at the lowest estimation in the proportion of three to two.

OF OVER-SHOT WHEELS.

It is explained by M. Borda in the memoir we are now adverting to, that if a water wheel of this class be required to produce its maximum effect, it will be necessary to observe the three following conditions:—1. That its diameter be equal to the height of the fall of water; or it may even be taken at somewhat more than that dimension. 2. That the current of water shall enter the buckets at the level of the surface of the reservoir. 3. That the velocity of the wheel be exceedingly small: but although the maximum of effect can in fact be produced only when these conditions are actually fulfilled, a gentle fall of the current or water, and a sufficient velocity of the wheel may nevertheless be admitted without reducing the effect of the wheel materially below its maximum of effect.

The author assumes for the purpose of an explanatory example a wheel of 11 feet in diameter, which he places in such a manner that the surface of the reservoir shall be situated at 12 feet from its lowest point, and that the first action of the water shall take place at the highest point of the circumference; and supposing the buckets to be allowed a velocity of 4 feet in each second of time, the resulting effect will be to the maximum effect as 11 to 12. But if it should be required to encrease the velocity to that of 6 feet in each second of time, it will in that case be found that the maximum effect will be reduced one-tenth.

He observes that it is thus shewn that bucket wheels do practically produce very nearly a maximum effect, whereas vertical wheels of the usual construction produce at most but three-eighths of the maximum effect; and that the two classes of horizontal wheels produce one of them somewhat more, the other a little less than half the maximum effect.

It is observed finally by M. Borda, that the practical application of the different sorts of hydraulic wheels here described, depending on a fall of water disposable at pleasure, on the nature of the machinery to which they may be required to be applied, and on many other local circumstances; no statement of general advantages can be made in favour of any of them, but that from the general principles he lays down in his memoir, a correct comparison of their merits can easily be made for any case which may occur.

(I 3. Plate 2.)

OF HORIZONTAL WIND-MILLS.

There is perhaps no machine more universally known than the wind-mill; or at the same time any machine of which the true theoretical principles are so little understood, and which are subject to such various inconveniencies. The vanes of this machine are turned by the direct impulsion of the wind; but the power which acts to produce this motion, is frequently less than that which tends to overturn the machine. From this circumstance there results the necessity in constructing the vanes, of making them of excessive dimensions: such enlarged dimensions greatly encreases the quantity of friction, renders the working with high winds both difficult and dangerous, and in the event of hurricane even exposes the whole machine to destruction.

The size of the wings occasion a very considerable lateral resistance; and if the obliquity be considered which it is necessary to give them in order to obtain the maximum of effect, it will be seen that on account of this considerable surface of the wings, the effect of the mill is seldom what might be expected. The necessity of constantly directing the wings to the wind is one of the

greatest inconveniencies; as the wind is continually varying, its direction is seldom such as is required. It sometimes may be found even to shift suddenly to the opposite point of the horizon: in such a case, the mill is in great danger of being destroyed; besides this, the inconveniences of the capstern, and the difficulty of working it with sufficient alertness involves much unprofitable labour, and occasions much loss of time.

In wind-mills of small size a set of vanes are sometimes used, which enable the wings to direct themselves to the wind; so that from whatever point it proceeds they immediately assume their proper situation. In England this is generally effected in large mills by a small set of vanes acting on a large horizontal toothed-wheel by means of an endless screw; but large vanes of this description, when applied to mills of small size, as well as small vanes, when applied to mills of large size, present obstacles of too serious a nature in their construction on the one hand, and of expence on the other, to meet with general adoption. These circumstances have engaged the attention of mechanical men, who have sought the means of some more advantageous use of the power of wind, which might enable a mill to direct itself constantly to the wind without the necessity of any manual operation. One of the most remarkable of these is a Dutch mill, in which is a horizontal wheel with moveable wings: a certain number of these are constantly in the direction of the wind, while the others are entirely exposed to its impulsion, and consequently force the wheel round till the power ceases, or some other cause stops the motion of the wings.

In the figure I 3, let us imagine—1st. That C 1, C 2, C 3, C 4, C 5, represent a wheel composed of six frames set upon the spindle C. 2nd. That e k, d y, b i, a h, g m, and f l, are small vanes fixed to the same frame by their pivots d', and that they are placed in such a manner that the vanes are divided into two unequal parts by their axis of rotation.

Let there be placed in each frame a check or stop as r r, &c. formed by vertical ropes at such a distance from the center as that the distance between the check and the pivot of the vane, which belongs to that frame, shall be a little less than the length of the longer arm of that vane. The vane will consequently be at liberty to turn freely on its pivot, without however being allowed to pass beyond

the direction of the supporting frame: which may be easily effected by introducing other checks, such as other ropes placed between those last mentioned and the point of rotation.

It will be easily perceived that in whatever position the small vanes may be during a calm, the moment the wind begins to blow, in whatever direction, the vanes will of themselves assume their proper direction, by causing the spindle C, to turn constantly the same way: this is a circumstance of great importance, and would certainly have given this description of wings a decided advantage over vertical wings, if serious inconveniencies incident to them had not materially lessened their value. That which we consider as the most important, is the considerable resistance which takes place between the wind and that portion of the wheel which places itself opposite to its direction. The continual shocks produced by the striking of the vanes against the check ropes, also diminish the general effect of the machine, and tend to its destruction.

It has been unsuccessfully attempted to diminish these consequences by encreasing the number of vanes upon the same frame; but daily experience shews us, that the general inconveniences attending horizontal wind-mills overbalance their advantages.

(K 3.)

OF WIND-MILLS WITH VERTICAL SAILS.

These mills are composed 1st of a moveable axis B, inclined to the horizon from 8 to 15 degrees. 2nd. Of four bars or arms of wood B C, B D, B E, B F, each of about 37 feet in length, which are set at right angles to the axis B, near its highest extremity. And 3rd, of four wings, which are supported by the last mentioned pieces.

The wings are each 31 feet in length, by a little more than 6 feet in breadth; and extend from 6 feet above the axis B, to the extremity of the bar.

According to Messrs. Monge and Hatchett each wing may be considered to be a bent or waved surface, generated by the motion of a right line perpendicular to the piece which supports the wing. At the extremity nearest to the axis B, the

wing makes an angle of 60 degrees with it on the windward side. The generating line traverses with an uniform motion the whole length of the piece which supports the wing, always remaining perpendicular to it, but uniformly encreasing the angle which it makes with the axis B, until arrived at the extremity of the wing. It forms an angle of 78 degrees with it, if the axis B is inclined 8 degrees, or of 84 degrees if the axis B is inclined 15 degrees; and in proportion for any intermediate inclination.

The several positions of the generating line spoken of, will give the position of each cross-piece of the frame which receives the sail of the wing.

Each wing may thus be considered a waved surface, generated by the motion of a right line perpendicular to the supporting piece, and coinciding in every part of its progress with a right line drawn between the corresponding extremities of the generating line at the two extremities of the wing as already described.

The dimensions here given are those which are generally adopted in Flanders, in the neighbourhood of Lisle; and are described by M. Coulomb, in a memoir of the Academy of Sciences for 1781, to which we refer the reader.

In calculating the total effect of these mills, he estimates that they will raise 1000lbs. weight 218 feet in each minute of time, working constantly at the rate of eight hours each day.

M. Coulomb observes with M. Bernouilli—supposing a man to use his power in the most advantageous manner, and to work eight hours per day, he will not be able to raise more than 60lbs. weight in each second of time: which, producing 1,728,000lbs. weight raised to the height of 1 foot, for the daily effect, we shall have upon the calculation of 8 hours' labour in each day, a total weight of 1,000lbs. raised to the height of three feet and six-tenths in each minute; and as we determine that the mill in question working at the rate of 8 hours per day, will raise 1000lbs. weight to the height of 218 feet in each minute, its whole effect will equal that of the daily labour of sixty-one men.

In the memoirs of the Academy of Berlin for the year 1756, we find a memoir of M. Euler on the theory of wind-mills: in which he determines that the wing should form an angle of 54 degrees 44 minutes, with the supporting shaft at

that point of the wing immediately contiguous to it, that at its extremity it should form with the shaft an angle of 80 degrees; and that the velocity of the extreme point of the sail should be somewhat more than twice that of the wind.

A memoir of M. Lambert, in the memoirs of the Academy of Sciences of Berlin for the year 1775, may be advantageously consulted on this subject.

The dimensions of the wings of wind-mills, their form, the methods of adjusting them to the direction of the prevailing wind, the means afforded of spreading, and of taking in the sails, are likewise considerations which have constantly engaged the attention of mechanicians and men of science.

The following works may also be beneficially consulted:

Leupold Theatrum Machinarum.

Description de l'art de construire les moulins, by Beyer; enlarged by Weinhold. Dresden, 1788, in folio.

Dessins artificiaux des toutes sortes des moulins á vent, &c. by Jean de Strada de Rosbery. Published by Octave de Strada, Frankfort, 1617, and 1629, in folio.

Theatrum machinarum novum, &c. by Gregorium Andream Bocklerum, 1662. This work also contains the greater part of the machines described in Strada's work. Bockler also published a work in folio, under the title of "Architectura curiosa nova," which contains a collection of such fountains as are remarkable by the variety of their arrangement and effect.

Schapp's work, entitled "Theatre des Moulins;" the mechanical portion of the first part, with five supplements. Frankfort, 1766, in quarto.

There are few collections of machines which do not contain accounts of various constructions of wind-mills *.

A description of two mills, which deserve some attention, will also be found in the Annales des Arts et Manufactures, Nos. 20 and 41.

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* As for example—in the "Collection des machines approuvées par l'Academie," in vol. i. pages 105 and 107; and in vol. vii, page 117.

(L 3.)

A description of a steam engine with a direct motion was contributed to the account of productions of the national industry, by M. Verzy in the year 1806, and which we shall now describe :—

Let a b c d be the section of a cylinder taken at right angles to its axis, and let the height of the cylinder be equal to the distance m n, which is the space that separates the cylinder a b c d from a second cylinder e f g h i e, situated concentrically within the first; so that the two cylinders have one common axis, and the surface of the second is accurately adjusted to the upper and lower edges of the first or outer cylinder.

Between the two cylinders there is thus a sort of circular channel, the horizontal section of which is represented in the figure by k e b f h l m n k e, and the height equal to the plate m n, which is attached to the outer cylinder and breaks the continuity of the circular channel already mentioned: the ends of the interior cylinder are closed by plates of metal, which form a small border or ledge on the upper edges of the exterior cylinder. They are attached to the axis C, so that the interior cylinder may be at liberty to turn freely about on its axis, supposing the exterior cylinder to remain fixed.

In the curved surface of the interior cylinder are made two apertures e i, g h, diametrically opposite to each other; and in width and height equal to the circular channel or passage already spoken of. Two shutters or valves of an angular form k e i, g h l, are provided, which turn on their axes e and h, and act so as to close the apertures e i and g h, and also the circular passage at the same time by means of two spiral springs e p q, h r s, fixed on the upper extremities of their axes, and the elasticity or force of which may be encreased or diminished at pleasure. These axes project above the upper face of the cylinder, and have each a lever handle which respectively project from the axis in the directions e k, h l.

The curved surface of the exterior cylinder is perforated by two circular apertures, one which terminates the tube A, which conveys steam to the cylinder, and the other communicating with the condenser by means of the tube B.

This being clearly understood, if we imagine that steam enters the cylinder by

the tube A, the plate m n obstructs its passage, whilst the two sides or arms k e, e i, of the angular valve presents the same quantity of surface, and consequently the valve will not alter its position; but its edge will press on that of the interior cylinder with the whole force of the spring e p q, and that cylinder will revolve about the common axis of the two cylinders, and in the direction a b c. Before k e arrives at the aperture B, which communicates with the injection pipe, the lever handle at h, will have encountered the obstacle or check at o, which is a small bar or pin fixed to the outer cover of the exterior cylinder, and will have forced the angular valve g h l within to turn inwards: thus passing the fixed plate m n, so that when it re-assumes its first position, k p will have passed the aperture B, and the vacuum will be formed in the portion k e b l r f p of the passage, and every thing will be in the situation represented in the figure. The interior cylinder will only have made a half revolution; the action of the steam will continue to communicate a continued rotatory motion to the axis, which may be applied to any use at pleasure.

Various machines on this plan have been constructed in England for a considerable time. Descriptions of such may be seen in the Repertory of Arts and Manufactures.

(M 3.)

PLAN AND ELEVATION.

The intended effect of this machine is to produce the immediate conversion of the rectilinear motion of the wind into circular motion. It is an universal windmill, but is not so practically useful as it is curious.

(N 3. Plate 10.)

THE MACHINE OF THE MARQUIS MANNOURY D'ECTOT.

The plate consists of an elevation, an horizontal section in the line cc′ of the elevation (marked a in the plate); and a second horizontal section in the line d′d of the elevation (marked b in the plate).

It is well observed by M. Petit, that this machine may be classed among hydraulic wheels:—it consists of a cylindric wooden tub n c d d′ c′ n, the bottom of which has a circular perforation r r in the centre, as represented in the

elevation and the section b. Through this aperture there passes an iron spindle p q, which is held at its upper extremity by a collar, and has its lower extremity resting on a pivot, which allows it a rotatory motion on its axis, and carrying the tub with it in its motion, by being attached to it by cross bars of iron, two of which c c′ and e e′ are shewn in the section a, and the other two d d′, f f′ in the section b. The spindle, which lies in the direction of the axis of the tub, does not completely occupy the circular aperture which it passes through, but leaves around it an open annular space through which the flowing water has liberty to escape. A circular diaphragm s s, fixed to the vertical axis p q, and also to the cross bar c c′ e e′ immediately below them, serves to divide the tub into two equal portions in the direction of its depth, as n c c′ n and c d d′ c. These divisions or compartments of the tub c d d′ c, have no means of communication except by the annular space which remains between the edge of the diaphragm and the inner surface of the tub. The lower portion or compartment of the tub c d d′ c′, is divided into eight smaller compartments by so many divisions t, four of these proceed immediately from the axis towards the circumference: the other four do not extend so far as the axis, in order not to cause too much obstruction to the opening r r. These diaphragms are composed of flat surfaces, and continue from the circular diaphragm to the lower part of the tub. Water is made to enter at the upper part of the tub by a conduit-pipe B, which is bent in a suitable manner so as to allow it to flow out by an aperture x shewn in the elevation, and in the section a. It flows in a sheet which strikes perpendicularly against the concave surface of that part of the tub, setting the tub in motion, and descending to its lower compartment by the annular space provided between the diaphragms s s, and the inner surface of the vessel, penetrates the eight divisions already spoken of, and finally quits the vessel by the aperture r r, and falls into the discharging pipe R.

This is the description and mode of operation of this machine, which the inventor has adopted in various different instances with perfect success. He has recently added an improvement which consists in substituting for the flat diaphragms t, curved or spiral diaphragms, which extend upwards as far as the upper edge n n of the tub, through the open space in the middle. The figure

of these improved diaphragms enables him to dispense with the flanch n n, and which prevented the water from escaping in that direction: it appears that by this improvement the loss of momentum is considerably diminished.

O 3. Plate 10.

M. CAGNIARD LATOUR'S MACHINE.

This machine is composed of two tubs or vessels A and B, the first filled with water at the ordinary temperature, the second filled with hot water the temperature of which is of at least 75 degrees of the centigrade thermometer. In the first tub is placed an Archimedean screw C, and in the second a water wheel D; a tube a b c d e f, communicates from the bottom of the first tube to that of the second.

If the Archimedean screw be turned in a direction contrary to that in which it would be necessary to turn it, in order to raise the water contained in the tub, it will cause atmospheric air to descend by its spiral passage; and this, after passing through the tube of communication a b c d e f, will be delivered at its aperture f. It is hardly necessary to premise that the distance of the aperture f from the surface of the tube B, should be somewhat less than that of the aperture a, from the surface of the vessel A. The cold atmospheric air, carried in this manner to the bottom of the tub filled with hot water, will under those circumstances, become dilated with the encreased temperature, enter the compartments of the wheel by the open or outer ends, which are turned downwards, and so cause the wheel D to revolve.

M. Carnot, in a report made to the Institute, May 8th 1809, upon this machine, observes thus:—In the machine executed by M. Cagniard, the effect produced is to raise by means of a rope attached to the shaft of the wheel a weight of 15 lbs. with an uniform velocity of one inch in each second of time, and in a vertical direction; whilst the moving power applied to the screw is only three pounds weight with the same velocity: so that the effect of the encreased temperature seems to be that of encreasing the natural effect of the moving power five-fold.

We may conceive that the effect of the moving power being encreased five-fold, we may deduct from that effect and add somewhat to the moving power; and still find that we retain a disposeable power of four times the original or moving power, which is what has been effected in M. Cagniard's machine, as will be seen by the figure.

This application of the Archimedean screw produces one of the best arrangements for blowing engines. At Clichy we find it adopted in a manufactory of white lead in which the screw is of the dimensions of four feet in diameter, and five feet in length.

(P 3. Plate 10.)

The appellation of Crab, is given to a machine composed of an horizontal roller, which is used to lift heavy weights, either by means of a simple pulley, or sometimes with the additional help of combined pullies of different powers; these machines afford a general solution of the problem proposed to be resolved in this section.

We have in this instance a machine of this description, in which the required effect as to the relative velocities is not produced by the use of a compound pulley, but by substituting for the ordinary cylindrical roller, a roller which consists of two cylindrical portions of different diameters, and on one common axis: see A E in the figure. A rope A B C D E, after making several turns on the portion A of the roller, passes over the simple fixed pulley B, and thence to the simple moveable pulley D, to which is attached the weight P; it then returns, and passing by a second fixed pulley C, goes finally to the other and smaller portion E of the roller A E, on which it is wound up in a contrary direction to that in which it was wound on the first portion A; so that when the cylinder is made to revolve on its axis, the rope is wound up, or gathered upon the portion A of the roller, while it is unwound or released from the portion E. The moving power is applied to the extremities of the levers I I. It will be easily conceived that at each rotation of the roller A E, the weight P will move through a space equal only to half the

difference of the circumferences of the two portions A and E of the roller; and it will also be evident that the difference may be made small at pleasure.

The description of a double capstern produced by an application of this principle will be found in vol. xix, page 305 of Les Annales des Arts et Manufactures.

SECTION IV.

To convert a given direct and equable rectilinear motion, or the velocity of which varies by a given law, into alternate circular motion of velocity similar to that of the moving power, either equable or variable by a given law; and in the same, or in different directions.

(A 4.)

IF direct rectilinear motion be converted into direct circular motion by any of the arrangements pointed out in Section 3rd, all the examples shewn in Section 9 will apply to this section.

(B 4.)

It has been proposed by M. Perrault, of the Royal Academy of Sciences (Recueil des Machines approuvées par l'Académie des Sciences, Vol. i. Nos. 9 and 10,) to apply the fall of water as a mover for a pendulum clock. Without pledging our judgement as to the usefulness or merit of his machine, we shall explain the organization he has adopted for converting the rectilinear direction of the moving power into an alternate circular motion.

Water is made to fall, as at c in the figure, into the vessel d, which is constructed to turn or swing on an axis m, and is divided in the middle into two equal parts by a partition. When the base of this vessel is in an horizontal position, the water falls so as to divide itself equally by the partition before mentioned, and in any inclined position the whole quantity of falling water will be received by that side of the vessel which is elevated. In the position shewn by the figure, this entire quantity is received by the side b of the vessel; when that side of the vessel becomes full, it turns on its axis in the direction of that side, and descends till it reaches and rests on the stop or support f, pouring out, by this change of position, the

quantity of water which produced the motion. The opposite side fills in its turn, and brings the vessel into its first position, resting on the support g; and the operation is repeated.

(C 4.)

Problem.—*To convert alternate circular motion into direct rectilinear motion.*

Let A B of this figure be a lever turning about on an axis C, and F G an upright bar, which is at liberty to rise and fall easily; and having a strait ratchet on each of its longitudinal edges. D E, D E are two small levers turning on pivots at D and D, and have their other extremities E E, turned so as to engage in the teeth of the ratchet already mentioned. The alternate circular motion of the lever A B will operate to raise the bar F G. M. Perrault, of the Royal Academy of Sciences, has applied a piece of mechanism of much similitude to this, to the construction of an engine for raising heavy weights. It will be found in the Recueil des Machines approuvées par l'Academie, Vol. i. No. 1.

(D 4.)

A boat at anchor in the middle of a river, if held by a cable of sufficient length, will move alternately from one bank of the river to the other, by means of its rudder; furnishing an instance of alternate circular motion from direct rectilinear: this is a well known contrivance, and is of frequent application.

(E 4.)

A sector of a circle surmounted with a sail, forming together a combination, the centre of gravity of which shall be situated considerably below the centre of oscillation, by means of the application of a counterpoising weight, will swing to and fro continually, with an alternate circular motion produced from the impulsion of the wind upon the sail: this mode of applying the direct action of the wind has been often proposed, and many models constructed on this principle may be found in the Conservatory of Machines of Paris; and in the work of M. Alexander Bailey, which includes the description of machines presented

to the Society for the Encouragement of Arts and Manufactures of London: the application of this contrivance as a first mover to an hydraulic machine by M. Merryman, will be found in vol. i. page 154.

All machines which are applied to the purposes of raising water by means of an oscillatory or alternate circular motion, communicated to the machine by any power whatever, and which is applied to them exteriorily, as are those for instance which are described in the Journal des Mines, No. 66, may be placed in this fourth class.

The Bulletin de la Société d'Encouragement, for August, 1811, No. 86, contains a description of a machine termed an Hydraulic Pendulum, by its inventor M. Boitias. M. Molard, in a report upon this machine, made by him to the Society in December 1808, and which is contained in the 54th Number of the work above mentioned, makes the following observation:—" With respect to the hydraulic pendulum, this machine must not be confounded with a contrivance under the same name, described by Belidor, for the purpose of raising water. It is a simple pendulum which receives its oscillatory movement by means of the current of a river, and with the additional aid of a counterpoising weight.

To produce this effect, the author has placed a float board of considerable size, and mounted on a supporting pivot, at the lower extremity of the pendulum; it alternately assumes the vertical and horizontal position. In the first it dips into the current and obeys its pressure; in the second it obeys the effect of the counterpoising weight, which brings it back to the position from which it set out, in order to commence another oscillation."

SECTION V.

To convert a given direct and equable rectilinear motion, or the velocity of which varies by a given law, into a direct curvlinear motion of velocity similar to that of the moving power, either equable, or variable by a given law, and in the same, or in different directions.

DIRECT rectilinear motion may be converted into direct circular motion by the methods exhibited in Section III.; and the arrangements shewn in Section X. will afford examples of the required conversion.

SECTION VI.

To convert a given direct, and equable rectilinear motion, or the velocity of which varies by a given law, into an alternate curvlinear motion, of velocity similar to that of the moving power, either equable or variable by a given law, and in the same, or in different directions.

DIRECT rectilinear motions may be converted into direct circular motions by any of the arrangements exhibited in Section III.; and then the examples of Section II. will afford instances of the required conversion.

SECTION VII.

To convert direct circular and equable circular motion, or the velocity of which varies by a given law, into alternate rectilinear motion of velocity similar to that of the moving power either equable, or variable by a given law, and in the same, or in different directions.

(A 7.)

LET A B D E, plate 2, be a wheel which is at liberty to revolve on its axis in the direction indicated by the letters A B D E with an uniform velocity;

m n is an index which is obliged to observe the same direction, while the extremity m follows the figure of a curve drawn on the surface of the wheel; the other extremity n, is also required to make a determined number of back and forward motions of given extent; and returning with each revolution of the wheel to the same point from which the motion commenced, and this with a velocity either uniform, or which varies by a given law, or which is even entirely arbitrary.

If the ratio of the velocities be uniform, or if they follow given laws, the curves which will be thus described will be determinate and easy of construction. On this subject a memoir of M. Deparcieux may be consulted on the mechanical methods of describing those curves which occur in the construction of machines intended to move levers or balance wheels. It is printed in the memoirs of the Royal Academy of Sciences for 1747.

If the ratio of the velocities be arbitrary, a solution of the problem may be afforded by a great variety of curves; and by rectilinear polygons as well as by curved. Rectilinear polygons afford angles too acute—curvlinear ones are therefore to be preferred.

The application of this problem is of considerable use in the art of turning.

(B 7.)

This is a particular case of the subject of the last problem, in which at each revolution of the wheel we obtain but a single alternate stroke, and that an uniform motion. The curve being proportional and all its diameters equal, that circumstance is rendered advantageously available by subjecting the motion of the rule or bar a b, to the curve, by means of two metal pins n m, which are fitted with friction rollers, against which the curve acts through its whole course.

The pieces which carry the threads in the bobbins of the silk-throwing machine of M. Vaucanson, are put in motion by an application of this curve. It is also used in different hydraulic engines to afford an uniform motion to the pistons of pumps.

In the 23rd number of Les Annales des Arts et Manufactures, we find the description of a new spinning-wheel by Mr. Antis, an Englishman, for which

the Society for the Encouragement of Arts, &c. of London awarded a premium to that gentleman.

C 7. Plan and Elevation.

Let A B C in the plan of the figure represent a plate of metal, through the thickness of which are cut the grooves or channels a b, c d, &c.: behind the plate A B C, and close to it, let us suppose a second plate N M (shewn in the elevation or upper figure); in this plate is cut, also through its thickness, the spiral channel indicated in the plan of the figure by the double dotted line, and described on the same principles as the curve of the preceding figure B 7: it is evident that if the small cylindrical pins r s pass through the intersections which the spiral will form with the channels a b, c d, &c. and the hinder plate be made to move, all the cylindrical pins will approach to, or recede from the centre by an equal distance. Now if the bent arms s n be added to those cylindrical pins forming radii to the circle, and their lengths be such that their extremities n shall terminate in the circumference of a circle concentric to the plate; it is evident that these extremities n of the arms, will in every position, whether advancing to, or receding from the centre, also be situated in the circumference of a circle concentric to the same circle. Two pieces of mechanism similar to this may be arranged one over the other, as is shewn in the elevation of the figure; and the extremities n of the bent arms may be connected so as to compose a kind of cylinder whose diameter may be encreased or diminished at pleasure by the rotatory motion of the spiral plates before described. This ingenious arrangement is adopted in England, in the construction of lathes, and in other machines in which it is occasionally required to alter the relation which the moving power bears to the resistance, and where it is necessary to effect this with quickness and facility. Other applications of this contrivance may be found in the Repertory of Arts and Manufactures, vol. xvii.; which contains the specification of a patent obtained by R. Brayshay—" for a machine for the purpose of gaining an increased speed and power to all mechanical operation by land and water:" dated October 30th 1801; and No. lxxi of Les Annales des Arts, &c. by R O'Reilly.

(D 7.)

The wheel A B (of which the figure shews a side elevation) has its periphery formed into teeth of any figure at pleasure: the arm a b is made to press constantly upon the teeth of the wheel by means either of a spring or the application of a weight, and is at liberty to slide through the pieces c and d, while it preserves its perpendicular position with the plane of the wheel. If the wheel be turned, it will communicate to the arm a b, an alternate rectilinear motion, which may be varied to suit the required purpose. It will not be difficult to determine the figure of the teeth upon the principles spoken of under the article (A 7).

A very ingenious application of this motion has been made by M. Zureda in his carding machine. The same motion has also been latterly applied to a machine for the manufacture of fishing lines.

Leupold, in his work " Theatrum Machinarum Hydraulicarum, vol. ii. p. 36. fig. 3, shews an application of this contrivance to a motion for pump pistons. The vertical axis of an horizontal hydraulic wheel carries another horizontal wheel, on the upper side of which are arranged seven inclined planes, forming a kind of ratchet wheel, having the spaces or intervals between the teeth nearly equal to the base of the inclined planes which compose the wheel; the piston rods of the pump are fitted with projecting pieces which rest on the wheel by friction rollers; so that at each revolution of the first wheel or mover, the pump pistons make seven ascending, and seven descending strokes, or seven alternate rectilinear motions.

(E 7.)

The circle A of this figure has a motion on its axis, and a projecting point or pin fixed on its face passes through the groove n m of the lever P Q, whose centre of motion is at R. It will result from this arrangement that the direct and uniform circular motion of the wheel A will be converted into an alternate circular motion; and the two extremities of the lever P Q will traverse with unequal velocities, and the machine will belong to the class of the ninth section. But if a portion of a toothed wheel be set on the extremity P of the lever which

shall act in the rack-bar N M, an alternate rectilinear motion of unequal velocity will be obtained, and which will belong to the arrangement of Section VII.

By means of the simple fixed pulley G, and the rope Q G H fixed at Q and sustaining the weight H we also obtain an alternate rectilinear motion of unequal velocity.

Another alternate rectilinear motion of unequal velocity will also be obtained by placing a pin or small cylinder at the intersection of the groove p q of the lever P Q, with a groove s t described in the fixed bar X y, the cylinder so placed will have the required motion.

Les Annales des Arts et Manufactures, vol. xv, page 119, contains an application of this motion to an improved machine for cutting the teeth of wheels.

(F 7.)

PLAN AND ELEVATION.

A is a wheel of which a portion only is toothed, and which turns constantly in the same direction on a fixed centre; B C is a chase frame, the two inner and opposite sides of which are formed into racks. To the ends of this frame are firmly attached the bars B S C T, which are at liberty to move to and fro within the clips p q, n m; the frame with its two bars, which may thus be considered as one piece, thus acquire an alternate rectilinear motion by conversion, from the direct circular motion of the wheel A. The frame which contains the two racks might also be applied to a bar, by a simple change of construction.

If the teeth of the wheel were infinitely small, they ought to occupy one half of its periphery and the remainder be left plain. The length of the two racks will be equal to half the periphery of the moving wheel, and their extremities will be at equal distances from the short sides or ends of the frame: but when the teeth of the wheel are of larger size, which must always be the case in practice, the toothed portion of the wheel must be less than half its periphery; the racks will be equal in length to the toothed portion of the wheel, and they will terminate at unequal distances frm the ends of the frame. The number of teeth for the wheel is arbitrary, but great mechanical precision is required in the practical execution of this machine.

The teeth of the wheel and of the racks will be described with sufficient facility by reference to the instructions for that process given by M. Camus, in the second volume of his " Course de Mathematiques" *.

When the portion of the wheel to be formed into teeth is determined on, and thence the length of the rack, and the situation of one of them, that situation of the other which shall afford the maximum effect in the entire machine may be easily determined by trial: the theoretical discussion would lead us from our view of the subject without affording adequate advantage.

Applications of this motion to the alternations of pump pistons may be found in the description of M. Augur's pumps, (Machines approuvées par l'Academie des Sciences de Paris, Vol. iv, No. 223).

Examples of the conversion of a direct circular motion, into an alternate rectilinear motion, by means of a wheel of which only a part is indented, and one or two racks; and also of the conversion of direct circular into alternate circular motion, may be found in the Repertory of Arts and Manufactures, London, Vol. xii. page 145; in Berthelot's work—Mécanique appliquée aux Arts, aux manufactures, à l'agriculture, à la guerre, vol. i. page 79; Moulin à pédale vol. ii. page 36; Machine à manége pour scier la pierre, vol. ii, page 40; Scie à débater le bois.

In the 1st volume of a work by J. Leupold, printed at Leipsic in 1724, entitled Theatrum Machinarum generale, chap. 12, the author undertakes to shew five different methods of converting direct circular motion into alternate rectilinear. The first of these methods which he shews in plate 25, figure 1 of his work, corresponds with our arrangement (F 7). This second method, plate 25, figure 2, is actually the same: the only observable difference is that the bar represented by T S in our figure (F 7) is vertical, and that the two racks instead of being toothed, are formed of a series of small horizontal cylinders similar to those which are used as trundles in the lanterns of mill-work; the motion of the bar TS is applied

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* Further information on the subject may likewise be found in " L'Essai sur l'Horlogerie," by F. Berthoud, Paris 1786, vol. ii, page 13; the 4th volume of the French Encyclopédie, article " Dent"; and the Dissertations of M. de la Lande, in " Le Traité d'Horlogerie de M. Le Paute.

to the piston of a pump: this application had already been made by Ramelli. The third method (figure 3, plate 25), does not materially differ from the preceding; it is in substance a lantern pinion, which is partly fitted with trundles, instead of a wheel partly indented, and the teeth of the rack are rounded. The fourth method (fig. 4) is composed of two vertical racks, having their flat sides placed parallel to each other, and their racked edges lying in the same direction. The upper extremities of these racks are attached to the ends of a rope which passes over a simple fixed pulley; the racks being thus suspended, it follows that whenever one of them is made to ascend, the other will descend by its own weight; an horizontal spindle is placed across the front edges of the racks, and two lantern pinions partially fitted with trundles are set on it so as to act on the racks; their positions are so adjusted in the first instance, that when the trundles of one of them act on the corresponding rack and cause it to ascend, the blank space of the other pinion is opposite to the other rack, which is therefore at liberty to descend. The author applies this mechanism to the movement of pump pistons in his work entitled, "Theatres des Machines Hydrauliques," printed in 1724, vol. 2, plate 40, fig. 8. In his fifth and last method, the author converts the direct circular motion into alternate circular, by our arrangement R 9, plate 7, in which B and C are two pinions, and A a wheel partly indented. He again converts the alternate circular motion of the bar d e of our figure, into an alternate circular motion by our arrangement (D 8), plate 5: for this purpose he places an endless screw on the horizontal bar d e, which works in the segment of a wheel; the extremities of the segment are continued horizontally, and carry the piston rods of two pumps. The description we have here given will shew that the five supposed methods of the author are reduced to one, the arrangement of which admits of but little modification.

By laying aside one of the two racks, and introducing an entire toothed wheel, the alternate circular motion may be converted into an alternate rectilinear motion, as will be shewn in our figure (M 17). This arrangement had long been applied in the process of coining—for milling the edges of the pieces under operation, but its use has since been discontinued.

A very simple and ingenious method of avoiding the loss of time which would

take place in this piece of mechanism at each change of direction of its motion, was invented by M. Doinet. An additional tooth marked a, in the figure (F 7) is set on the wheel A, but below the level of the other teeth of that wheel. An additional tooth is also set on each rack, and in the same plane or level with the additional tooth of the wheel. The action of the tooth a, upon the additional teeth of the racks operates to continue the motion of the bar T S during the interval which elapses between the action of the wheel ceasing on one rack, and its commencement on the other.

In Bockler's work, already mentioned in speaking of our figure (E 3,) we find the direct circular motion of a vertical spindle converted into an horizontal and alternate rectilinear motion by the arrangement we have described in our account of F 7. A vertical spindle carries an horizontal lantern pinion, the trundles of which work into two rows of pins arranged upon the inner edges of a frame, which is thus substituted for the racked frame of our figure. In Bockler's machine it may be observed by figure 71, that each rack is terminated at the opposite ends by a pin somewhat longer than the rest: this is evidently intended to correct the loss of time incidental to the changes of direction. The author then converts the horizontal alternate circular motion into the vertical and alternate rectilinear motion, required for working pump pistons, by an intermediate alternate circular motion, which he effects by a contrivance similar to our figure N 7, plate 3: thus—To the end of the piston rod he fixes a bar which extends to the edge of a cylinder or horizontal circle, whose axis is perpendicular to the vertical plane passing through the piston rod, and the spindle of the frame; another bar is placed from one end of the frame to a point upon the edge of the cylinder 90 degrees distant from the attaching point of the bar first mentioned. These bars turn freely at their ends, as the bar n m in our figure N 7. This mechanism resembles that in common use in bell-hanging, for transferring alternate rectilinear motion from one apartment to another. He also shows other applications of the same arrangement.

G 7. Plan and Elevation. Plate 3.

In this arrangement the frame containing the racks is made somewhat larger

than that of the preceding article, by having the racks themselves longer, so as to meet at the ends, where they continue in a semicircular form, and the small wheel or pinion is completely toothed. It has been found necessary to allow a small lateral motion to the rack-frame, which is given at the end of each alternation by means of two cross pieces a b, c d, in order to facilitate the change of direction of the rack. In general however, this motion involves considerable difficulty in the practical execution; and it appears but little adapted to produce any important effect.

In a report made by Messrs. Prony and Mollard, upon the methods proposed to replace the hydraulic machine of Marly, we find a machine projected by M. White, in which this motion is introduced.

In Bockler's work—Theatrum Machinarum novum, &c. the same mechanism is applied to convert the direct circular motion of an horizontal spindle into an alternate and vertical rectilinear motion for pump pistons: Bockler's contrivance for equalizing the motion of the rack-frame does not appear of sufficient merit to recommend it to notice; but in the course of this work we shall introduce a variety of methods for that purpose.

H 7. Plan and Elevation.

This is a modification of the motion shewn in F 7. In this machine the number of teeth in each rack is reduced to one, and those of the wheel are entirely superseded; they are replaced by projecting arms, each having a small friction roller at its outer extremity. It will be readily observed that this strait figure of the teeth of the racks will occasion an irregularity in the rate of their alternate movements; but the law of this velocity may either be varied at pleasure, or rendered uniform, by making the teeth of a suitable figure.

The construction of this machine is to be preferred to that of F 7: for all arrangements which are exposed to violent action, and to which small teeth of the usual form and dimensions would not offer sufficient resistance. The engine in this form will be less costly in its original construction, and will be made with greater facility: incidental repairs will also be more easily made.

In the first volume of "Machines approuvées par l'Académie des Sciences", we find this movement applied to the construction of a machine for sawing stone, &c.; and another application of it in the "Traité de la Gravure à l'eau forte" of the old Encyclopedia.

I 7.

In this figure A represents a wheel which turns on its axis; n and m two clips between which slides the bar P Q, with the attached cross-bar R S; s is a pivot which is allowed to pass through the groove p q. The circular motion of the wheel A will under this arrangement produce an alternate motion to the bar P Q.

This alternate rectilinear motion is very slow at its commencement, but is accelerated as it approaches the middle of each alternation: it is evidently extremely simple and easy of construction. This is also a modification of the arrangement shewn at F 7.

In the first volume of "Machines approuvées par l'Academie des Sciences", this contrivance is applied to the construction of a machine for sawing marble. It is used in the ribbon weaving machine, to give the stroke for throwing the shuttle; and is also sometimes used in domestic economy, in a machine for churning.

In the eighth volume of the Repertory of Arts and Manufactures, we find this movement adopted by Mr. Bunting, in his calendering engine. His first mover is a horse, which is applied to turn a vertical spindle; at the upper extremity of this is a pinion which drives an horizontal wheel. The direct circular motion of this wheel is converted into an alternate rectilinear motion by the means already described; the height of the arm which receives this motion being inconvenient, the author transfers his alternate rectilinear motion to another arm lying in a parallel direction to the first, and at the required height, by means of an intermediate alternate circular motion E 17. The polisher of his machine is fixed to this second arm.

(K 7.)

The alternate rectilinear motion of the bar P Q R S, figure I 7, may be readily equalized by substituting a groove of the curve represented at p q in the figure, for the strait groove pq, of the figure I 7.

The method of describing this curve is very simple: the distance C s is divided into a certain number of equal parts, as for example six, s1, 12, 23, 34, 45, 5C; and the quadrant s D is to be divided into a like number of equal parts. It is evident that the conditions of the problem will be obtained if that point of the bar P Q which corresponds with the point s of the figure be made to coincide with the divisions 1, 2, 3, &c. of the radius s C, at the same time that the pivot s itself shall coincide with the corresponding divisions 1, 2, 3, &c. of the arc s D; it will be necessary therefore to determine the position of the points 1, 2, 3, &c. of the curve p s q, so that each shall be placed with relation to the point s, as the corresponding points of the arc s D, are placed with relation to the points of the same name in the radius s C, which will not be found difficult. The same process will be followed for each of the three remaining quadrants of the circle.

L 7.

In this figure a b is a vertical bar, which slides between the two rings n m; a pestle is fixed on its lower end b, on one side of the bar is fixed a rack in which works the indented portion of the wheel A, the remaining part of which is without teeth. When the plain portion of the wheel is opposite to the rack of the bar, the pestle P will fall by its own weight upon the body M: but if the wheel be made to turn in the direction of the dart in the figure, when the teeth arrive at the rack, and begin to act, the pestle will be gradually elevated; but will fall again when the plain portion of the wheel again arrives at the rack, and this alternate motion will be continued with the action of the wheel. This is another direct instance of the arrangement F 7. It is in frequent use for machines for the purpose of bruising and pounding hard substances.

If for the rack and bar were substituted a toothed wheel which should turn in the same direction as the pinion A, either by a weight P, attached to a rope, which should be wound on its axle, or by a spiral spring: the direct circular motion of A would be converted into an alternate circular motion, and the arrangement would be classed in Section 9.

This mechanism was applied to work the pistons of two pumps by De Caus,

an architect and engineer, and is described by him, in a work entitled "A new invention for raising water above the level of its source, by means of certain hydraulic machines." London, 1644.

The author caused a vertical wheel having half its periphery indented, to turn by the immediate action of a moving power, and on the right and left of this wheel he placed two others of equal diameter, and which he supposed to be partially indented, but which might also be completely indented, according to the construction described in our last article; he communicated each of the piston rods of the two pumps with one of these wheels by means of a rope attached to the end of the piston rod, and by its other extremity winding about the cylinder or spindle of the wheel; the rope was so wound on the spindle that the piston acted by its weight to turn the wheel in the direction which converted the direct circular motion of the moving power, into the alternate circular motion of the lateral wheels; and consequently the pistons received their required alternate rectilinear motion; one of them ascending while the other descended by the action of its own weight. The author in order to facilitate the descent of the piston, caused a rope to pass over a simple fixed pulley placed over the middle wheel, and afterwards to wind itself about the axis of the two lateral wheels, and in the same direction with the corresponding ropes of the piston rods; so that when one of the pistons was raised, a part of the action of the moving power was at the same time employed to assist the descent of the other; the wheel being turned in the proper direction, the piston had to overcome a resistance at least equal to the inertia of the wheel, with its friction, and the rigidity of the rope, and in short, a resistance equal to the power required to set the wheel in motion.

M 7.

This is a modification of the mechanism of the preceding article. The teeth of the rack are reduced to a single one, and the wheel is fitted with cams or curved projecting pieces, the curvature of which is such that the resistance becomes uniform. The construction of these curved pieces is simple; a description of them will be found in the memoir of M. Deparcieux, which

we have before spoken of under the article A 7. This contrivance is applied to the same practical uses as that of the preceding article.

N 7.

The circular motion of the wheel A communicates by the intermediate operation of the bar n m, an alternate rectilinear motion to the bar p q, which is allowed to slide between two clips, one of which is shown in the figure at t. If the wheel A be used as a fly wheel, the motions will be reciprocal.

The length of the alternate rectilinear stroke made by the rod p q will be more or less, in proportion as the point of rotation m, is more or less distant from the centre of the wheel A.

If the bar p q be taken away, and the bar n m be made to pass through a circular opening which we will suppose to be made in the clip t, the bar n m will then have a compound alternate motion, similar to that of the bar E F G, in our figure L 10. Plate 8. In the first volume of Bailey's description of Machines, in folio, we find an account of a silk reel used in Italy; in which the guides receive their alternate and horizontal motion by an application of this contrivance; the point marked m in our figure is supported by a frame which slides in a groove, upon the surface of the wheel A; so that it may be shifted with facility to any required distance from the centre. The wheel A is placed in an horizontal position, and receives its rotative motion by means of an endless band, the constant and equal tension of which is preserved by providing the wheel A with an horizontal adjustment; the wheel is carried by a bar of wood having a sliding motion in a vertical piece which supports the whole; a suspended weight acts constantly to draw the wheel A from that which is set on the spindle of the reel.

(O 7.)

A B in this figure represents a cylinder having a rotatory motion on its axis; on the surface are cut two spiral channels or grooves similar to those of a screw, their paths round the cylinder are cut in opposite directions, so that they intersect twice in each revolution, and join or run into each other at each end of the cylinder; C is a projecting piece accurately fitted to the spiral grooves and is attached to the arm C D, which passes through a longitudinal

groove or passage cut in the fixed cross-frame E F. Under this arrangement the rotatory motion of the cylinder will produce the alternate motion of the piece C, by passing alternately from the first or direct spiral groove, to the second or reversed one. This motion is extremely ingenious, and is capable of extensive application; it was communicated to us by the inventor M. Zureda, a Spanish mechanist of great professional merit.

P 7.

A B is a cross frame in which a mortice p q is cut, and in this the spindle of the pinion n is at liberty to move freely. C D is a bar the periphery of which is formed into a continued rack and is driven by the pinion, it is attached to the bar or piece which is to receive the alternate rectilinear motion, and the latter is made to slide through the clips a and b. When the racked bar C D is carried by the action of the pinion to the extent of either of its sides, the check-pieces α and β act on the springs r s, u t, which oblige it to return by its other side.

This movement is difficult of construction: it has been suggested as applicable to machinery for cutting the tops of piles, but as the teeth of the pinion cannot be made of sufficient strength for any engine in which great power is required, we do not consider it proper for such purposes.

Q 7. Plan and side Elevation.

A B C, in the plan of this figure, represents a flat circular ring, the inner edge of which is toothed; D is a toothed wheel which works into the wheel A B C: its diameter is equal to the radius of that wheel. The bent axle n m p q, revolves on the centre of A B C; its extremity n supports the wheel D by its centre, while its other extremity p forms a handle, to which the moving power is applied to produce the rotation of D; while this wheel revolves on its centre, and traverses the toothed inner edge of A B C, each point of its periphery will describe a diameter of that wheel. The demonstration of this theorem is given by De la Hire, in his Traité des Epycicloides, et de leur usages dans la Mécanique. Mém. de l'Acad. Vol. ix. page 389.

A model of this movement was presented at a late exhibition of productions of the National Industry, by M. White. His description of it may be seen in les Annales des Arts, vol. xix.

R 7.

Two toothed wheels A and B, arranged as they are shewn in this figure, will produce an alternate motion, of which the alternations, their extent and velocity, may be infinitely varied, either by altering the ratio of their diameters, or the proportions and arrangement of their several parts. These motions may, however, be accurately produced by the arrangement shewn in the figure A 7.

The combinations shewn in the figures S 7 and T 7 are of the same nature. An instance of this description of alternate motion may be seen in plate 21, vol. i. of the plates of manufactures of the French Encyclopédie.

U 7. Plan and Elevation.

In the plan of this figure a b c is a flat circular ring, which has a small portion cut away, and which has a continuous series of teeth formed both on its outer and inner edges; the portion of the ring which is cut away is of sufficient width to allow the pinion d to pass freely from the outer edge to the inner, and after having made the circuit of the inner edge, to pass at its opposite extremity again to its outer edge, and the ring is fixed to the circular disk or plate D, which has a motion on its axis.

The pinion D has a motion on its axis, and this has also a liberty of motion in the groove n m; two springs p and q act alternately on the projecting stops or detents r and s, and so determine the quantity of the alternate circular motion of the disk D; this is a modification of the arrangement shewn in the figure P 7. The alternate circular motion of the disk D is used as an intermediate motion to produce the alternate rectilinear motion of the point F: this is effected by means of an endless rope which passes round the disk, and over the two fixed pullies S and T. This example in strict propriety belongs to Section IX: we introduce it here as a judicious method of using an intermediate motion; and to shew the analogy which exists between this and the subject described in P 7.

It would be difficult in practice to make the pinion d work with equal facility on the interior and exterior edges of the ring on account of the difference in their teeth: this difficulty may however be avoided in a great degree, by placing two pinions d one above the other on the same axis, and making a corresponding separation between the planes of the interior and exterior teeth; so that they shall act only on their respective pinions, as is shewn in the elevation of the figure.

A 7′ Plate 4.

We have here combined two well-known methods of converting direct circular motion into alternate rectilinear motion, by using a bent axle, or a circular plane inclined to its axis of rotation. M. Prony gives a theory of bent-axles in the Journal des Mines.

In the fourth volume, No. 266 of Memoires approuvées par l'Académie, we find an application of this axle to the motion of a piston by M. Laesson. The author gives a very simple mode of constructing an axle of which the crank may be lengthened or shortened at pleasure.

In Leupold's Theatrum Machinarum Hydraulicarum, vol. ii. pl. 36, fig. 1 & 2; and in Ramelli's work, entitled—Le diverse et artificiose Machine del Capitano Agostino Ramelli, &c. a Parigi, 1588, figure 57.—This method of the inclined circle is applied as a motion for pump pistons. An hydraulic wheel turns a vertical axle which carries an inclined circular plane; the vertical piston rods have projecting arms with friction rollers, which are supported by the edge of the inclined plane: in this way the circular motion of the vertical axle of the water-wheel produces the required alternate rectilinear movements of the pump pistons. The vertical position of the piston rods is provided for by grooves with friction rollers. A second projecting arm from the piston rod, which applies itself to the under side of the inclined revolving plane, operates to assist the descent of the piston and to equalize the motion.

B 7′.

The large wheel R revolves on its axle, and three rollers m n p, are placed on its

surface; a bent lever PGH, the arms of which are set at right angles with each other, carries a roller p at the extremity P of the arm PG, the action of a spring or weight applied to the extremity H of the other arm tends to give the roller p a constant bearing against the rollers m, n, p, which will therefore, by the rotation of the wheel R, act in succession on it and cause the alternate circular motion of H; this will consequently belong to Section IX.: the alternate circular motion may be converted into alternate rectilinear by means of a fixed pulley f. This motion has been applied by M. Genssane to the construction of a contrivance which he used as a substitute for lever handles. See Machines approuvées par l'Académie des Sciences, Vol. vii. No. 442.

C 7′.

S is a fly-wheel carrying a pinion p; P and Q are two toothed wheels acting on each other, and P is also driven by the pinion p; n m, s t, are two lever handles set on the axes of the wheels P and Q; m f, s g, are two rods both the ends of which have free motion, and they are connected by a cross bar f g with the vertical and larger rod H R, to which they communicate an alternate rectilinear motion during the regular action of the fly-wheel S:—the motion is reciprocal.

The application of this movement may be seen in a memoir on a new steam engine invented by Cartwright, and inserted in the first number of Les Annales des Arts et Manufactures. Two pins might be fixed on the peripheries of the wheels P and Q instead of the lever handles; but they are retained for the greater facility of construction. In No. 25 of the same Journal the Editor proposes a new steam engine, in which he adopts Cartwright's fly-wheel instead of a beam.

D 7′. Plan and side Elevation.

S is a fly-wheel, on one extremity of the axis of which are fixed two ratchet wheels R R; within these, two toothed wheels are fitted on the same axis, but remain at liberty to turn independently on it. Each of these has a click p,

which is placed in the same direction on each, and on the outer face, so that they act upon the ratchets only by turning in opposite directions ; P Q is a large bar which slides between two clips, and dividing itself into two parallel pieces forms a frame furnished on the inner edge of each side with a rack f g and h i ; these are not situated in the same plane, the rack f g being a little distance behind the plane of h i, so that h i acts on the wheel M, and f g on N. If we suppose the bar P Q to move from Q towards P, the rack h i will be brought to act on the wheel M by the effect of its click p, and will communicate a rotatory motion to the fly-wheel in the direction shewn by the dart in the figure; the rack f g will at the same time act on the wheel N in the opposite direction ; but the click of the ratchet belonging to N does not hold the ratchet during the upward motion of the rack f g ; the wheel N will pass round on the axle independently, and will not therefore impede the progress of the fly-wheel in the direction already given it by the action of the wheel M. When the frame returns from P towards Q in its descending stroke, the click of the ratchet belonging to the wheel N is in action, and operates to hold the wheel N, so that the rack f g turns it together with the fly-wheel, in the direction shewn by the dart as before. If one of these wheels M or N, together with its rack were omitted, the direct motion of the fly-wheel would nevertheless continue as in the movement G 9 ; but as the action of the moving power upon the fly is in that case unequal, the mechanism in the state here described is preferable. No reciprocal action takes place in this instance.

OBSERVATION.

IF a wheel having a constant motion in one direction by the action of any mover, receives another wheel on its axis which is held there by its friction only, being capable of motion on the axis independent of the first, any method which might be invented for alternately attaching and disengaging the first wheel, might also be used either to communicate to the latter the action of the mover, or to withdraw it from such action ; in the latter case, it will remain at rest, if by its inertia, or the resistance it is enabled to offer to the second wheel, it could overcome its friction ; or it will obey the action of any other power tending

to give it motion. It is thus we are enabled to suspend the operation of a machine, without the necessity of interrupting the action of the first mover, or to withdraw it from the action of the original mover, in order to connect it with some other. We find this occur in the action of bells. We shall give an account of some ingenious methods of releasing the ram of the pile driving engine, although we consider the arrangement shewn in the figure I 7′ as the most simple and effective, and one which may be universally adopted with advantage. We shall however first shew the methods which may be employed, 1st to check the motion of the machine while the action of the mover is suspended, without subjecting it at the same time to any effects of resistance; 2nd, to avoid the accidents which so frequently occur in all machines which are required to produce great power, such for example, as capsterns, presses, the machines used for cleansing harbours, &c. &c. whenever from violent shocks or other causes the resistance causes a retrograde motion upon the mover, and communicates it to the machine, or when the cables, chains, &c. by means of which the action of the machine is transmitted to the resistance, happen to meet with fracture or derangement, and the machinery thereby acquires a greatly accelerated movement in that direction; 3rd, to avoid the vexatious consequences which result from such derangement in any part of the machine, whether from natural obstacles or such as accident or ignorance may occasion, as place the resistance beyond the powers of the machine to overcome.

In order to check the motion or action of the machine, during the suspension of the action of the first mover upon it, without subjecting it at the same time to the effects of the resistance, it is usual to employ a ratchet wheel with a click which puts it in action, while it operates to check the action of the mover in a gradual manner, as is effected in the ordinary methods of working the capstern, &c. &c.*

* In the 14th Report of the Society for the Encouragement of Arts, &c. for 1815, we find the description of a very singular click and ratchet movement, invented by M. Dobo; M. Borgnis, in his work entitled "Traité de la composition des Machines," places it as the 17th variety, 4th species, 1st genus, 2nd class, 5th order—Regulators.

When the resistance is thrown on the mover, the retrograde motion of the machine generally produces so considerable a shock, that the attempt to counteract it by interposing any firm resistance similar to that produced by the common click and ratchet movement, becomes not merely useless, but even dangerous; in such cases, the most proper course, is to effect a gradual weakening of the shock, for which purpose no method can be used which is in our opinion so likely to be effective as the retarding force of friction, applied by a check or curb, either to the axis of rotation, or perhaps more advantageously to the surface of a drum or barrel of considerable size, fixed on that axis. An arrangement of this method is adopted in England for lowering heavy weights from considerable heights to which they have been raised by machinery; this contrivance is curious and judicious; its description is as follows.

Let A Figure 1 of Plate 12, represent a toothed wheel, which is driven by a pinion B immediately connected with the moving power; the weight to be operated upon is suspended at the extremity of the rope D, which passes over the fixed pulley shown in the figure, and returning thence is gathered up on the axis C of the wheel A; t represents one of the pivots of that wheel; the check is composed of the lever m n, moving on its point of rotation or fulcrum q; to the longer arm m q is fixed the pad or cushion p, this presents a concave surface to the axis C, on which it may be pressed by the lever, the counterpoise H serves to raise it from the axis, and the check pin shown at r, stops it at a convenient elevation.

When it is required to release the weight suspended by the rope D, the pinion B must be withdrawn from the wheel A, or thrown out of gear, or it may be detached from the action of the moving power by the method I 7′; the weight will then be rapidly lowered, and when it has arrived within 3 or 4 feet of the ground, where from its accelerated velocity it would be dashed to pieces, the operator presses down the lever by its extremity m, with considerable force and so brings the cushion p to bear on the axis with so much friction as immediately to counteract and check the progress of the falling body.

In a work entitled "Traité élémentaire de Minéralogie," by M. Brongniart,

vol ii, page 302, we find the description of a drum-wheel, the motion of which may be instantly checked when circumstances require it, whatever may be the effort of the moving power: by means of a curb composed of two stays or clips similar to that already described, and which together form a sort of large nippers, the spreading of the extremities of the arms of these clips or nippers, renders it necessary to place a small capstern in the middle point of their separating distance; this capstern is worked by the operator when he finds occasion to check the action of the machine.

The following description will explain the method of tightening the curb.

Let A, Figure 2, Plate 12, represent the drum-wheel set on the shaft or axis of the machine, this wheel has on one of its ends a ratchet wheel R, and it revolves on its axis in the direction indicated by the dart shewn in the figure; m n is the lever of the curb; p the cushion; c c a click suspended by the rope f, to the extremity b of the lever a b, which moves on the point a, as a fulcrum, and rests by its arm on a small roller which is fixed in the end m of the lever n m; the timber frame F has a projecting point s, which prevents the click from rising or leaving its position, while the spring v acts to press it forward to its operation on the ratchet-wheel, and by its curvature, keeps it up to its proper bearing while it is in action. If the motion of the drum-wheel should be reversed the click will be drawn into immediate action on the ratchet-wheel, the lever n m will operate to press the cushion p on the surface of the drum-wheel, and the motion of the machine will be checked without violent shock, and consequently with the least possible inconvenience.

Let us now suppose the machine to be rapidly drawn in the direction of its motion; and (in order to avoid the unnecessary multiplication of figures) let the drum-wheel A in the same figure be imagined to turn in a contrary direction to that indicated by the dart; it will be necessary to suspend the action of the spring v on the click c c, by means of a pin, so as to allow it liberty of motion, and so that in case of any sudden and extraordinary acceleration, the check pin shall cease to act on the spring, and the action of the machine shall be checked as in the preceding case; for this purpose

the regulator N 7′ Plate 5, and the motion G 8, of the same plate may be used; the wheel A of this motion represents the drum-wheel A of figure 2, and the spindle of the regulator may be represented by the axis of the wheel B, of the figure G 8, Plate 5, and which should be placed in the upper part of the wheel A, figure 2.

The tension of the rope Q which communicates the action of the mover to the resistance, may also be applied to profitable use, by using it to keep the click c c in its detached situation with respect to the ratchet-wheel; when in the event of the rope breaking, the click will be instantly released from its detached position, and will be submitted to the action of the spring r, which forces the click into action with the ratchet-wheel; the mechanism of this contrivance will be less complicated than that of the preceding article, and its action quicker; it consists simply of a very small cord d d, which is attached by one end to the lower part of the spring r, and by the other end to a small bar g g, which slides between the clips g′ g′, the bar carries a small roller t, which is so adjusted that the rope Q may press strongly against it, the cord d d is extended between the bar g and the spring, by small rollers, as shewn in the figure; it will be evident that if the rope Q should be broken, the roller t will be instantly released from the pressure which enabled it to hold the click c c from its action, the click will therefore as quickly be forced into immediate operation on the ratchet, and the motion of the machine will be checked.

The machine represented in Figure 3, Plate 12, is much used in the neighbourhood of Paris for the purpose of raising large masses of stone from the quarries. The celebrated machinist, M. Martin, considered that the adoption of this machine would prevent the disastrous accidents to which the workmen in that employment are so much exposed; its construction is thus. A lever p q composed of a stout plank, is suspended on the fixed point a, as a fulcrum; the shaft of the wheel A passes through the plank at the point c, and a counterpoise Q capable of raising the wheel A is suspended at the extremity q; the machine in this state resembles in its general features the common steel-yard, on which the wheel A occupies the place of the mass to be weighed, and in which the usual moveable weight is superseded

by the counterpoise Q; in the arrangement of our machine however, no equilibrium is produced, it being necessary that the counterpoise should exceed the load. B C is a strong upright pillar, and f e an edge piece of timber which has a motion on the point f as a centre, and carries the cushion q; e d is a bar either of wood or metal, having motion on the axis of rotation e and d; n n is the rope by which the masses of stone are brought from the quarry P; r is a ratchet wheel fixed to the axis of the wheel A, and r its click which is attached to the upright pillar B C. It will be evident that an upright piece corresponding with D E must be placed on the opposite side of the wheel A, in order to support the axis of suspension a of the lever p q; and also, that the latter must be forked, and its sides at a sufficient distance to allow a space for the free passage of the wheel A. The mass required to be raised must be attached to one of the ends of the rope n n, and on the first action of the weight upon the wheel A in the direction indicated in the figure by the dart, the short arm of the lever p q will descend, together with the wheel, until the end p of the lever is checked by some firm resisting obstacle, on which it will rest: the cushion p will be raised, and the working of the machine will proceed without any interruption; it may however be suspended at pleasure by means of the ratchet wheel, and whenever the rope n should happen to break, the wheel will instantly be raised by the action of the counterpoise Q, the cushion q of the curb will descend and apply itself upon the drum wheel, and the shock will be prevented.

In Bailey's work already spoken of under the head E 4, we find in the first volume page 146, the description of a crane invented by Mr. Pinchbeck. In this machine a curb is brought into action for the same purpose, but the mechanism is much too complex for general adoption, even if it were fully equal to the proposed object. The mover which operates to press the curb against the wheel, is the action of large bellows which are worked by machinery.

Whenever the resistance of a machine exceeds a determined limit, the action of the mover may be checked in the following manner:—

In the figure 4, plate 12, the lower or shaded figure represents a longitudinal section of the parts of the arrangement to be described, and the three upper or outline figures, transverse sections of different portions of the same.

Let M be the axis or spindle acted on by the moving power, and N that which is connected with all the other parts of the machine: now it is required that whenever the resistance encountered by the machine exceeds the assigned limits, its safety shall be secured by the facility of checking it without the necessity of interrupting either the action of the moving power, or the connection between the two axes M and N.

A A is a circular plate of iron fixed upon the spindle N: the surface which is turned towards N is flat, but on the opposite side are formed the two projecting rings n n and m m.

B B is a second circular plate of iron—on the side nearest to the plate A is formed a projecting ring p, which fits easily into the cavity formed between the plate A and the piece b; on the opposite side are two projecting pieces a a, intended to act against the projections ss of the piece C; and a strong projecting stud b, which extends beyond the opposite surface, enters the space formed by the ring or circular spring D D; performing the office of the curb.

D D, is a ring or circular spring which clips or holds upon the neck formed by the edge of the plate A and its projecting ring m m; this ring or curb may be closed or tightened at pleasure by means of the key E, (see the upper or outline figures) and consequently will encrease or diminish the friction, according to the required or convenient degree of resistance, in order that the motion of the spindle N shall be stopped while that of M shall remain at liberty to proceed. When the communication between M and N is completed, by means of the piece C which turns with it, and is at liberty to slide in the direction of its axis, (as in the wheel C of the figure I 7′, plate 4.); the projecting teeth ss act on the projections a a, the piece B and the curb are in action, and the whole moves together. When the piece C is withdrawn from the piece B, the connection of the projections ss and a a ceases; and whatever may be the resistance of N, the action of the moving power on the machine is suspended.

It is evident that if the key E be firmly closed, and the communication between the two axes be completed by advancing the piece C as directed, the axes M and N will act conjointly as if composed of one piece; but if by withdrawing the piece C, we detach them completely, the axis M will in its retiring motion take

with it the piece B and the curb D D, but the axis N will remain at rest; therefore if the key E be just closed so much as that the axis N may be at liberty to turn, the object of the arrangement will be accomplished with facility.

A very ingenious and important application of this mechanism has been made by M. Béttancourt in a machine constructed by him for cleansing the harbour of St. Petersburgh.

In our article L 7′, will also be found a method of securing a machine from any hurtful or inconvenient effect of the action of the moving power within certain limits.

E 7′.

A machine for driving piles invented by M. Camus.

The ram A is attached to the extremity of a rope which passes over the pullies B and C, and is afterwards wound on the vertical cylinder D, which with the lever I, compose the principal part of the machine: its action depends on the manner in which this cylinder is arranged and acts with the capstern, of which it forms a part; the capstern and the cylinder are of the same diameter and are set on the same axis; the cylinder should be encircled or bound with an iron strap E F, from which should project two or four points or pins also of iron.

The capstern G supports the lever H I, which carries a curved piece or heel F, which applies one of its ends against the cylinder, and the other end is attached to the capstern by a joint or hinge, so that it may be lowered by pressing upon its extremity I, and raised or kept up to its position by the spring L. The machine is put in action by applying the power of men to the horizontal levers O, M, N, P, who by their means turn the capstern G, and also the cylinder D, which is attached to the capstern by the lever F I applied to one of its iron pins; in this manner the rope by which the ram is suspended is wound up on the cylinder, and the ram is raised the height of the upright frame V y. When it has arrived at its greatest height, the man situated at the end of the bar N, presses on the end I of the lever I F and forces it down; the iron pin of the cylinder which was held by the heel F of the lever being thus released, the cylinder is at liberty, and the ram by its gravity rapidly unwinds the rope from its

surface and descends; the lever I F is now released from the pressure which held it clear of the cylinder, and the action of the spring L raises it to its former position, the heel F becomes again engaged with one of the pins of the cylinder which is thus again connected with the capstern, and the operation is repeated.

We may here observe that the ram of this engine, and all those which carry the suspending rope with them in their fall, lose a considerable portion of their momentum by that circumstance.

(F 7′.)

The upper figure of the view of this machine represents a side elevation; and the lower figure an horizontal plan of the central part of it.

An iron spindle p q, turning constantly in the same direction, is shewn in the side elevation: this is moved either by the power of men whose action is applied to the bars of a capstern, or by any other suitable mover: it passes through two drums or cylinders of wood A and B which are not fixed to the spindle, but are fitted easily upon it.

The lower drum or cylinder A rests on the bottom board or floor of the machine: it is formed at its upper part of two rising surfaces a b c, a′ b′ c′, one of them on the exterior of the figure, the other on the interior, each making one turn of its circumference, similar to a hollow screw, or an open and winding staircase formd of one continuous inclined plane. These surfaces are so arranged that each has its origin a and a′, and also its termination, at the two extremities of the same diameter. This lower drum A has a ratchet wheel r, and a click s (shewn in the lower figure) which acts to prevent the ratchet from turning in the direction of the moving power.

The upper drum B is hollow, and is furnished with two vertical arms or bars n m, each having a small roller at its lower extremity, the length of the bars is equal to the height of the lower drum; the upper drum is supported by these rollers upon the inclined or spiral surfaces formed on the lower drum, and by which it always preserves an horizontal position. The upper drum also carries a strong bar of iron terminating at the height of the lower surface, and its outer surface is grooved to receive the suspending rope of the ram.

When the rollers of the arms n m are situated at the commencement of the inclined planes of the lower drum, the upper drum is at its lowest position or point of descent, and if it is then turned in the contrary direction to that which we suppose the moving power to take, that is to say, in the direction c b a, the two rollers will meet the heads of the rising planes and oblige the drum A to turn in the same direction. But if B be made to turn in the direction of the mover, A will remain at rest, and B, turning by means of its rollers upon the inclined planes will be raised to their height.

The iron spindle p q, has a strong cross-piece i i′ also of iron, placed so that it nearly touches the upper part of the cavity of the drum B when it is situated in its lowest position.

This description being clearly understood, the mode of producing an alternate rectilinear motion from the direct circular motion produced by the moving power upon the spindle p q, may he explained in few words. We will suppose 1st the drum B to be placed at its maximum of descent—2nd the cross-bar i i, in contact and ready to act on the upright bar t—3rd the ram M, resting on the head of the pile—and 4th the rope d d′ in a state of tension; the spindle p q will in its own rotatory motion carry with it the drum B; this will raise the ram of the engine to an height equal to the circumference of the drum; the bar t will then pass the cross-bar i i, and the drum B, thus subjected to the effect of the ram M, will turn rapidly in the opposite direction and suffer it to fall. The drum B will consequently have an alternate circular motion while the ram M will have an alternate rectilinear motion, and it will traverse a space equal to the circumference of the drum B.

If all the parts of the machine be supposed in their original positions, and the lower drum A be turned half a revolution, in the opposite direction to that of the mover; in this case, when the upper drum B has also made half a revolution, the ram M will fall; the extent of the circular oscillations of the drum B, and those of the ram will be thereby reduced one half.

This very ingenious mechanism admits of firmness and simplicity of construction, and possesses, as we have shewn, the further advantage of allowing the

ramto traverse any required distance from the smallest to a quantity equal to the circumference of the drum B.

G 7′.

This figure includes two views of the machine—one a front, the other a side elevation, the same parts being respectively marked with the same letters of reference.

A B is a spindle which is turned by the moving power always in the same direction; the wheel C, grooved on the edge, fits easily on the spindle A B so as to be at liberty to revolve with friction, but is not allowed to traverse on the spindle; on one of its faces is fixed a check-pin s; n m is an elastic bar or arm fixed to the spindle A B; r is an inclined plane placed a small distance beyond the circle C, and in the same plane; the rope c t has one end fixed in the grooved edge of the wheel C, and the other is attached to the flail or beater p q, which moves easily on the pivot p.

When the spindle A B revolves, the elastic bar n m meets the check-pin s, and obliges the circle C to revolve, which raises the beater p q: the bar n m also encounters the inclined plane r, and being thus forced from its contiguity to the circle C, suffers the check-pin s to pass; the circle C is immediately subjected to the action of gravity of the beater—which falls—and the process is repeated.

This arrangement, which is in reality but a modification of that shewn in our figure E 7′, has been applied by M. Dubuisson to a machine for beating or pounding plaster: a description may be seen in the "Collection des Machines approuvées par l'Académie des Sciences." Vol. vi. No. 407.

H 7′.

The following description of this machine is extracted from the report made by Messrs. Prony and Molard, upon proposals relative to the re-establishment of the machine of Marly: printed by order of the National Convention at Paris, in the third year of the French Republic.

DESCRIPTION OF WHITE'S MACHINE.

Page 15—The following is a description of the detent wheels: "The piece A is fixed to a spindle which revolves constantly in the same direction; and the wheel B is fitted on the spindle so as to be capable of being turned upon it with friction, in the contrary direction. This wheel is furnished with a detent C, to which the piece A catches, and thus elevates the chain D, to which one of the pump pistons is attached: this continues to rise until the detent C arrives at and presses upon the check-pin E; the piece A is immediately released from the detent, and the piston which is attached to the chain D descends by its gravity, at the same time causing the wheel B to revolve on the spindle in its reverse direction."

I 7'.

A B is a spindle, which we will suppose to revolve constantly in the same direction by the action of any moving power; C is a toothed wheel which is fitted on the spinde A B so as to have the liberty of revolving on it with moderate friction; and a b are two mortice holes to receive the check-pins m and n; D is another circle or wheel also fitted easily on the portion p q of the spindle A B, which instead of being circular as in its other parts, is there made quadrangular. The two check-pins m and n, are fixed on this wheel; and the forked lever f h, is used on the fulcrum r to force it to or from the wheel C, and consequently to place the check-pins m and n into their respective mortice holes, or to withdraw them at pleasure.

Every part of the machine being situated as represented in the figure, it will appear that the wheel C may either remain in a state of rest, during the action of the spindle A B, being prevented from accompanying it in its rotation by some external check: or it may obey the action of another mover which shall urge its rotation in a direction contrary to that of the spindle A B; in short, it may be considered as really independent of the motion of the spindle; except insomuch

as it is connected with it by the quantity of friction with which it is fitted to it: but if, by means of the lever f h the wheel D is moved so as to force the check-pins m and n into the mortice holes of C, the latter will necessarily obey the action of the spindle A B, until D, with its pins m and n, are again withdrawn from C, and so on. The action of the spring c is upon the extremity h of the forked lever, tending to withdraw the wheel D from C; the detent s t, of which both a plan and profile are shewn in the figure, moves on the axis i, the check e on one side, and the spring k on the other, determine the direction, and limit the extent of its movement; if the forked lever be turned so as to perfect the communication between the wheels C and D, the spring will be checked by the detent. When it is required to detach the machine from the action of the mover, a slight pressure must be made on the extremity t of the detent, the spring c will act on the end h of the lever, the wheel D will be withdrawn, and the required suspension effected.

This mode of checking the action of a machine may be practically applied to several useful purposes, as for example: to stop a mechanical operation at a required time without the necessity of personal attendance, in the working of mills when the operation of grinding is complete; or in the weaving-loom, when the flight of the shuttle is accidentally interrupted.

The first-mentioned of these objects presents no difficulty in the application: it will be merely required to arrange the weight of a repeating watch so as to act on the extremity t of the detent, which may for this purpose be rendered delicately sensible.

In mill work, the machinery may be stopped when the required operation is completed, making use of the last-mentioned contrivance—to call the attention of the operator to the necessary adjustment of the detent.

In the operations of weaving, accidental interruptions of the shuttle are of frequent recurrence, by the breaking of a thread, or other unforeseen circumstances. To prevent the disorder which must otherwise be the consequence of such accidents, the following application of this contrivance is made.—The shuttle frame traverses with an alternate circular movement, (see the Section A, Figure T, in the compartment K 7′, pl. 4.) its axis of rotation being in c passing through the

lower framing of the loom, the alternate circular motion of the frame should not be equable, its velocity being required to decrease as it approaches the extremity a of the arc a b, described by its motion ; we will suppose this extremity of the arc to be on the side nearest to the large roller, and that the decreased velocity at that point is required to allow sufficient time for the shuttle to pass from one side of the frame to the other, according to the width of the loom, and the velocity of the frame is required to be more or less accelerated as it approaches the extremity b of the arc, in order to strike the woof. Let an iron rod extend the whole length of the frame, having a free motion on its axis p, and at each end a bent lever n, p, m, r, which by the action of a spring placed near the middle of the bar, are constantly pressed forward so as to occupy the situations n′ p′ m′ r′, while the shuttle, on arriving at the points which it occupies at each alternation of repose will force them back to their first-described position n, p, m, r, it will be seen that if the shuttle meets with no interruption in its course, but passes freely, the levers n p m r will not meet the obstacles α and β when the frame by its alternate circular motion traverses the arc a b to strike the woof; but, if on the contrary it is interrupted in its passage, the levers which will then assume their second position n′ p′ m′ r′ will first meet the point or object α which receding from its action, will descend, and acting on the extremity t of the detent will effect the separation of the wheels C and D as already described, and they immediately afterward meet the fixed check B; the action of the mover will be detached from the machine, and the frame will consequently not strike the woof, which was the object required.

This motion I 7′ makes an instantaneous communication of the action of the mover to the machine, which is in some cases seriously inconvenient; it may be avoided in a considerable degree by the use of the mechanism Figure 4.

The extremely simple contrivance of this subject (I 7′) renders it useful in mill work to suspend the action of one of the stones of a mill where several sets of them are worked by one principal wheel, or where direct circular motion is to be converted into alternate circular, as in large flatting-mills, and indeed in almost every machine in which it is occasionally required to check the action of the works without interrupting the action of the moving power.

K 7′.

This is another modification of the preceding arrangement:—A B is a spindle which turns constantly in the same direction by the action of the moving power; the wheel C transfers the rotatory motion to the wheel D, which is fitted by friction only on the spindle E F; a pin e projects from the face of the wheel D, and another projecting pin f is fixed in the spindle E F; the wheel D may be placed within the action of the pin f, or be removed from it by means of the lever P Q; it will be evident by simple inspection of the figure that the action of the spindle E F may be suspended at pleasure by the requisite adjustment of the wheel D with respect to the pin f.

L 7′.

This machine is described in Les Memoires de l'Institut, and in Les Annales des Arts & Manufactures; vol. xix. page 181. It is the invention of M. Prony.

The organization of his machine consists in fact of an extremely ingenious application of the contrivance by which we detach, or communicate at pleasure the action of the moving power, and the axis of a wheel which is fitted on it by its friction, and reciprocally.

A large horizontal wheel A B is turned by the immediate action of the moving power, and drives in contrary directions the two vertical wheels C and D, which are fitted by their friction only upon the horizontal spindle E F; the interior face of each of these wheels has a ratchet wheel n and m: on one of the extremities of this spindle is fixed the wheel or pulley G, upon which is coiled a rope or chain, to each end of which is suspended a bucket, as shewn in the figure.

A frame a a composed of two iron bars, carries two ratchet wheels p and q, one at each of its extremities, and it is at liberty to slide back and forward on the square spindle E F by means of square boxes, which are fitted to, and slide upon it.

It is evident that if the frame a a is pushed towards the end E of the horizontal spindle E F, the ratchet wheels q and n at that end of it, will be placed in

action, and the axis E F will then revolve in the same direction as the wheel D, but if the frame a a is pushed towards the end F of the horizontal spindle, the ratchet wheels p and m will be in action, and the axis EF will revolve in the direction of the wheel C, and one of the buckets which are attached to the chain will ascend, while the other will descend. All that now remains is to communicate this alternate movement to the frame a a, so that it shall take place immediately after the rising bucket has emptied itself into the trough; and so that the chain of the rising vessel shall itself regulate the movement.

The inventor effects this by placing an horizontal spindle S S below E F, and in a direction at right angles to it. This second spindle is of iron, and has an arm x which projects upwards, and into the sliding boxes of the frame a a; it has also a long upright arm h, which is surmounted by a weight of lead of lenticular form, and below are two flat pieces or feet s and t; two forked pieces are placed near the extremity of the chain, just above the buckets, so as to act in succession on the two levers M and N. Those levers act upon the feet s and t, elevating them so that the upright bar h declines from a vertical position at the moment when the rising bucket is completely emptied; the weight P then produces a quick oscillatory movement of the spindle S S, and its arm x drives the frame a a towards the end of the machine over which the weight P inclines, and retains its position long enough to produce the operation of the ratchet wheels of that end of the spindle as already described. The spindle E F revolves in the contrary direction, and so on *.

M. Prony has also contrived a very ingenious method of releasing the animal used as the first mover, whenever the resistance is accidentally encreased. The following description of it is inserted in Les Annales des Arts, vol. xix. p. 190.

The traces 1, 1, 1, figure f pass through the apertures 2, 2, in the yokes 4, 4, which are attached to the levers 3, 3, this lever is set in the vertical spindle which gives motion to the machine; the apertures 2, 2, have friction rollers. The

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* We find an application of this movement in a machine for rifling gun-barrels, invented by M. Jacquet; a description of which is given in Le Bulletin de la Société d'Encouragement, Sept. 1817.

extremity of each trace terminates in a loop which hangs on a stud or pin, fixed in the roller 5, which is moveable on pivots. A rope is coiled upon this roller which afterwards runs over the pullies 6, 6, 6, and is finally attached to the weight 7.

This weight, which may be varied at pleasure, will therefore regulate the resistance required to be opposed to the effort of the mover: thus—suppose this weight to have been fixed at 20 lbs. and that any obstruction took place in the working-part or wheel-work of the machine, it will follow that, without the assistance of this mechanism, the effort of the animal or mover would cause the derangement or destruction of the machine; but as the effort of the mover necessarily exceeds the regulating weight, the roller 5 will be forced to describe one-fourth of an entire rotation on its axis; the studs or pins of this roller having thus left their former vertical position, the traces which were attached to the roller by them, will be allowed to slip off, the animal or mover will be liberated, and the machinery will suffer no derangement. This method will also be found applicable to the purpose of preventing animals employed as first movers from exerting more than a given quantity of power, which can be determined at pleasure by the previous adjustment of the counterpoising weight 7.

M 7′. Plate 5.

In this figure which is a side elevation of the subject, a b represents a vertical spindle which has a rotation on its axis, by the action of any mover applied at a; its lower pivot rests on a block of wood e, this has two rollers which work in a groove or channel cut in the cross-piece n′ m′; by this means the spindle a b is brought into contact with the two vertical wheels F and G alternately, and act upon them by an endless screw h. C and L are two cross pieces which support the spindle a b, at the same time allowing it sufficient space for the vibratory motion given it by the piece e. On this piece may be observed two click pieces a′ b′, c d turning on the points a′ and e, which as well as the two pins or ends b and d which proceed from their extremities, are of sufficient extent to reach the surface of the metal piece u m n. (For a more minute and distinct view of these parts

see the separate and enlarged figure m in the margin of the principal figure). This piece has an axis g f, from which at about the middle of its length, proceed at right angles to its direction, the two forked branches i l, which are intended to conduct the ropes which support the buckets; and near the extremity g of the arm f g is fixed an upright arm carrying the weight P; in the cross-piece will be observed two projecting pins x and y, having the quantity of their projection equal to the thickness of the two click-pieces a′ b′, c d; two buckets are attached to the ends of a rope which passes over the cylindrical backs of the toothed wheels F, G, taking one revolution on each. The action of the machine is as follows:—

All the several parts of the machine being in the positions represented in the drawing, the upright arm u, after having pushed the pin a′ towards the left, throws the endless screw h within the action of the toothed-wheel F, and the click piece a′ b′ falling by its own weight, comes in contact with the pin x, and throws the spindle and its endless screw into action with the wheel. When the projecting button s, which is placed a little above the bucket s, enters the forked piece l, the piece u n m is obliged to revolve on its axis; and the arm n, coming into contact with the pin b, disengages the click-piece before it reaches its horizontal position: but on the instant of its passing that position, the counterpoising weight P falling on the other side, the arm u presses on the pin c, and drives the vertical spindle within the action of the toothed wheel G, while the click-piece c d descends by its weight into contact with the pin y. The two cylinders on which are placed the wheels F and G, will therefore move in different directions, and the bucket S will descend while the opposite bucket rises, and so on in succession. On the edge of each bucket is a piece of iron which, when the vessel arrives at the proper height, receives a hook which operates to overturn and empty it. This machine is invented by M. Bettancourt.

In a work entitled—Branca (Giovanni) le Machine, volume nuovo e di molto artificio del Signor G. Branca, ingigniero et architeta della santa casa di Loreto. Rome 1629, 4to. (Italian and Latin.) Figure 21. The author shews the application of two vertical face wheels fixed on the same axis, and placed opposite to each other; a horizontal wheel turning constantly in the same di-

rection, is forced into action with the two wheels alternately, by an assistant. Thus communicating an alternate circular motion to the common axis of the two vertical wheels; this method of converting the movement is applied in many different machines.

N 7'.

In this arrangement it will be observed that, in proportion as the rotatory motion of the spindle a b encreases or diminishes, the weights p and q are driven from, or suffered to approach the axis of the spindle by their centrifugal motion, and the cap r, which fits easily on the spindle, rises or falls upon it; the action of a steam valve m, is made to depend on this vertical movement of the cap, and the machine by this means preserves nearly an uniform velocity although the resistance be variable. We have seen this contrivance used with great effect in England in a wind-mill for the purpose of raising the upper mill-stone, when its velocity becomes too great, and to prevent the meal from being improperly heated. The singular ingenuity of this application will render an account of it interesting.

The upper mill-stone A, (figure n 7'.) receives its movement from the upper side, as in the usual construction of wind-mills. The stone is supported by the axis a b which rests on the block C, fixed to the beam D E. Upon the spindle is fixed the cap fg, which carries four arms for the purpose of receiving the stems of four iron balls h, i, k, l, each from four to five pounds weight; from the upper part of the stems four arms descend and support the piece F, which is at liberty to slide easily the entire length of the spindle; a groove is cut on the edge of the piece F, to receive the forked end of the lever d, e, to the other end m of which is suspended one extremity of the beam D E, its other end being supported by the jointed bolt n.

It will be evident that the arrangement of balls, here described, will revolve about the axis, with the motion of the upper mill-stone, and that in proportion as the force of the wind encreases the velocity of the mill, the balls will encrease their divergency from the axis; the piece F will descend, will consequently lower the extremity d of the lever d, e, m, which having the point e for a ful-

crum will operate to raise the end E of the beam DE, and consequently the upper mill-stone A.

This mechanism has been applied by M. O'Reilly, in his blowing engine.—Annales des Arts, vol. x. page 26.

In Bockler's work, already mentioned, under the article E 3, figure 19, we find the description of a mill which is put in motion by the action of a horse: in this mill we may observe a piece of mechanism which is used for raising or lowering the upper mill-stone. This mechanism differs from that before described in that the lever d e m, instead of being parallel to the beam D E, is placed perpendicular to it; and that its motion does not depend on the velocity of that of the mill. The author simply suspends a weight to the extremity d of the lever d m, and which he adjusts at pleasure as to its distance from the point of rotation or fulcrum e, (as in the case of the common steelyard) for the purpose of regulating the distance of the mill-stones; but the interval remains uniformly the same so long as the position of the weight remains unaltered. In figure 47 of Bockler's work, he shews an application of the same mechanism to a water-mill.

Ramelli, in his work already mentioned in our Article A 7', figure 120, had before this made a similar application of this mechanism.

O 7'. Plan and Elevation.

The description of a mill which is worked by the operation of the flux and reflux of the tide, invented by Leslie of London, is given in Les Annales des Arts et Manufactures, vol. xxii, page 302. The operation of this mill being simply to convert an alternate rectilinear motion, into a direct circular motion, we shall merely insert its description as it is given in the work mentioned.

Figure 1—Is a horizontal plan or section of the wheel, with its outer cover or case.

Figure 2—Is a vertical section.

a, represents the spindle or shaft of the wheel revolving on a pivot of metal which works in a bed of steel.

b b, are wings of the wheel, a little inclined so as to admit the influx of the water in a spiral direction.

c c, A drum or cylindrical case, within which the wheel revolves, leaving the smallest space possible between the partitions and the wings.

d d d d—A second drum or case of larger diameter, placed above the wheel, and forming an upper structure to the drum c c, with which it is also connected.

e e—moveable shutters, opening on opposite sides: the first, which is on the side in the direction of the current, opens by the pressure of the current, and is stopped at its proper position for that purpose by an upright timber f; the shutter of the opposite side will of course be pressed by the action of the current in the opposite direction, and will therefore be closed by the same action which opened the first. The inverse of this operation will take place, when the water which has risen during the tide of flood or increase, seeks egress at the tide of ebb: the dotted lines of the figure will sufficiently indicate this reverse movement.

Now, let us suppose h h in figure 2, to represent the surface of a river or current which is at the level of the cover of the upper drum or compartment at the ebb-tide, so that there shall be the same quantity of water always acting on the wheel if the surface of the current should happen to be above the upper edge of that compartment, the water which runs above, even if elevated several feet, will not produce any greater effect than when it reaches but to the level of the cover.

Let i i represent the bed of the river, and if it has not sufficient depth, it may be encreased by digging*. The current penetrates the drum by the opening e, causing the latter to rest itself against the check f, by this admission it passes to the lower side of the machine by traversing the spiral wings of the mill, which are thus put in action by the impulsion of the current, and produce a rotatory motion of the vertical spindle; the current having passed through the machine

* We consider this practice as entirely inadmissible—for the resistance which the running water will meet with from that portion of the column which is at rest, will diminish its velocity, or even reduce it altogether.

and reached the bottom, escapes by the opening or shutter k; this is the process during the tide of ebb: on the contrary during the tide of flood, the shutters or openings mentioned, (k and e) will close, and the opposite ones will be opened, by which the water or current will descend as before, and the wheel will continue to turn in the same direction whether the current be that of the ebb or flood tide.

The peculiar advantages of this wheel over those of other contrivances for tide mills are these:—

1st—It is to be preferred for a corn-mill on account of its velocity being more uniform, from the circumstance of its motion being produced by the constant action of the same quantity of water.

2ndly—It has the peculiarity of its motion being produced constantly in the same direction, whether by the flux or reflux, and in a much more simple manner than in other tide-mills.

3rdly—The wheel being horizontal, it is very easy to adapt and fix any required wheel-work upon the spindle, the spindle being easily raised above the surface of the water.

4thly—This wheel has a greater velocity with respect to the velocity of the acting current, than other wheels of the same description; and this circumstance enables us to dismiss all the contrivances practised in the old wheels to counteract or diminish friction.

With respect to the construction, the inventor states that its simplicity is highly favourable to economy in the first cost.

We find descriptions of many different mills which act by the same moving power, in l'Architecture Hydraulique de Belidor.

P 7'. Plan and Elevation.

In the upper figure or elevation, A B represents a fixed vertical axis or pillar of very solid construction: it is surmounted by a toothed wheel C. A hollow cylinder D is placed upon the axis, and rests upon a projecting ledge at its lower part. Four cross pieces a b, c d, e f, g h, project horizontally from the

cylinder D, and are placed at right angles with each other; at the extremity of each of these cross pieces or arms is suspended a commodious seat or chair, and upon the face of one of the arms (a b) is set a small toothed wheel D′ revolving on its axis, and working with the wheel C. The wheel D has a small lever handle E from the upper extremity of which proceed four ropes, each of them passes over a small fixed pulley, and they are fastened at the extremities of their respective arms.

A person seated in one of these four chairs can easily communicate a direct circular motion to the small wheel D′, by means of the rope, which passing over the pulley is situated directly in front of the seat, and by applying an alternate rectilinear action to that portion of the rope * he will be himself carried round with a circular movement which will include the entire moveable part of the arrangement of which he forms a part, and which will thus compose a sort of fly-wheel.

It will always be in his power to vary or modify at pleasure the velocity of this direct circular movement of the machine.

If instead of one person, we suppose two, three, or four persons to be seated in the chairs, it will be necessary for them to apply the action in concert, so that they do not counteract each other.

This ingenious machine was invented by M. Marcel Cardinet, and was secured to him by brevet of invention or patent; his object in the invention was the material improvement of a popular amusement, by dispensing with the manual labour by which the machine was then impelled, and affording the parties themselves the important advantage of regulating their velocity, and of stopping the motion of the machine at their pleasure.

Before this application by M. Cardinet, the same mechanism had been applied to the construction of a watch by M. Breguet, in which the regulating parts revolved about an axis, under such an arrangement, that the relative positions of all its parts were continually changed; and this, as the inventor conceived, afforded an effectual remedy for many serious inconveniencies and imperfections

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* Similar to the action used in rowing.

of watches of the usual construction. The application of the idea to this practical purpose was worthy the reputation of an artist of his distinguished merit: but certainly the coincidence of invention does not lessen the merit or impeach the ingenuity of M. Cardinet, who, as we fully believe, was unacquainted with M. Breguet's invention; it affords a very remarkable instance of the relation which science establishes among branches of knowledge, where to superficial observers there seems no analogy.

Q 7′. Plate 11.

Let A represent the plan or upper side of a wheel having a ratchet wheel a b c d on its face of the same diameter; e f and d g are two arms, which are each at liberty to turn freely, by one of their ends on the axis of the wheel A; f g and h g are two other arms forming with e f and d g an irregular quadrilateral figure, of which the angles at f and g are nearly right angles; the several extremities of these arms are united by centre pins upon which they are at liberty to turn freely; h i is an arm connected with the quadrilateral arrangement of bars already described, by its extremity h; the three arms h i, h f, and h g, are also held by a centre pin upon which they have free motion; the arm h i passes through the clips k and l, and is therefore confined in its movements to the direction in which they are placed; the two arms e f and e g carry two click pieces m and n, one of them placed to the right, the other to the left of the figure; these two click pieces are connected with the arms by hinges, and they enter, and are kept to their action in the notches of the ratchet wheel, either by their own weight or by the operation of a spring. If now the arm h i be moved in the direction h i, the click piece m will act upon the ratchet wheel, and cause the wheel A to revolve in the direction indicated by the dart in the figure, while the click-piece n will slide over the teeth of the ratchet wheel; but if the arm h i return from i towards h, the click-piece n will then act, while the other piece m will slide over the ratchet; in each of these cases, the wheel A will revolve in the same direction. The alternate rectilinear motion of the arm h i will thus be converted into the direct circular motion of the wheel A.

R 7′. Plate 11.

Let A represent a wheel from which there projects the six pins 1, 2, 3, 4, 5, 6; and h p a horizontal bar supported by the rollers B and C; the bar h p has a projecting piece DE, the length of which is equal to the distance d e, between the bar h p and half the arc 1, 2, which separates the pins 1 and 2; F G H is a bent lever composed of the two arms F G and G H placed at right angles to each other, this bent lever is at liberty to turn freely on the joint G, the length of the arm G H is equal to the radius of the circle A, the centre point G is situated in a line G K, drawn through the centre K and parallel to the bar h p, and the arm HG tends constantly to descend by its weight; f is a pin or check which is attached to the bar h p, the horizontal distance of this pin upon the bar, from a vertical line drawn through the joint G, is equal to the distance D d. Now, if under these circumstances, the wheel A be made to turn in the direction indicated by the dart in the figure, the pin 1 acting against the projecting piece D E will draw the bar h p from h towards p, while the pin 5 will raise the bent lever F G H; when the pin 1 arrives at the point e, its action on D E will cease: the arm G F of the bent lever F G H is then in a vertical position, and will begin to act on the pin f of the bar h p, which will therefore make a retrogade horizontal motion in the direction p h; when the pin 5 of the wheel A arrives at the position 6, it quits the arm G H of the bent lever, which falling by its weight rests on the pin 4 which is then in the position 5, the pin 6 at this time occupies the position 1, and the same alternated motion is repeated, so that at each entire revolution of the wheel A, the bar h p makes six movements to the right, and six to the left. We find this contrivance adopted in a machine for polishing clock springs, described by M. Thiout, in his Treatise de l'Horlogerie Mécanique et Pratique; printed at Paris 1741. Vol. i. page 85; the same work also contains descriptions of several clock and watch scapements.

S 7′ and T 7′. Plate 11.

These two contrivances for converting direct circular motion into alternate

rectilinear, afford an approximating solution of the problem. They are sometimes adopted in the construction of steam engines.

In the figure S 7′, n m is the crank of an axle n, which receives its circular motion from the first mover, D is a bar attached to the extremity p of the piston rod of a pump, and which will then traverse on the line b b a distance which approximates to twice that of the crank arm n m. The lengths of the arms B and C, and the position of the centre of rotation F, is arbitrary. The bar C is placed in the three positions F t, F q, and F r, which it will occupy at the middle and the extremities of the course described by the point d of the arm D; this will determine q, r, and s for the points of opposition which the other end of the bar B will have at the same time; if a circle be described through these points, its radius will be the length of the arm A, and its centre, the point of rotation. A few repeated trials will be found to afford results sufficiently accurate for practice.

In the figure T 7′ are also given the lengths of the arms E I H, and the point of rotation F; the points n, m, and r are determined as in the last example; and the radius and centre of the circle which passes through them, respectively give the length of the arm L, and the situation of K its centre of rotation.

SECTION. VIII.

To convert a given direct and equable circular motion, or the velocity of which varies by a given law, into direct circular motion, of velocity similar to that of the moving power, either equable, or variable by a given law, and in the same, or in different planes.

A 8.

THE two toothed wheels A and B act on each other in the usual manner; the direct circular motion of the one, is communicated to the other, which is situated in the same plane, but the direction of the communicated motion is of course in this instance, contrary to that of the mover; if a motion be required in the same direction, a third wheel C must be added to the arrangement: the

ratio of the velocities will be determined by that of the diameters. If n be supposed to represent the radius of the wheel A, and n′ that of the wheel B, and if n and n′ are whole and prime numbers, the two wheels A and B will after certain revolutions, resume the same relative positions, if the number of revolutions of the wheel A be equal to n′, and those of the wheel B be equal to n. A very ingenious and practical application of this property of circles of unequal radii has been made by M. Breguet, the younger, in the construction of watches, in the following manner:—the fusee is laid aside in this description of watches, and the barrel or cylinder A, (see figure 5, plate 12.) which encloses the spring, has a toothed wheel $\alpha\,\beta$, by which the action of the spring is transmitted to the pinion of the first wheel in the train; the spring is attached by one of its extremities to the axis r d, and by the other to the interior concave surface of the barrel; the length of the spring is such that supposing it entirely released, the axis r d may make twelve revolutions to bring it up to its maximum of tension; in general, the mean tension of the spring is that which is employed, that is to say, the tension produced by four mean revolutions of the axis; the ratchet wheel λ is applied to prevent the arbor from turning in the contrary direction to that in which the barrel is impelled by the spring; and finally, the advantage of suppressing the fusee results from the principle of the escapement itself: the inequality of the action of the spring being compensated by the unequal action exerted on the escapement during its repose. This being understood, the inventor has set a toothed wheel B upon the axis r d, acting on a second wheel C, which is fitted easily upon a cylindrical stud or pin which stands upon the upper face of the barrel, a broad and flat-headed screw is tapped into the upper end of the cylindrical pin, and thus secures the wheel C; the diameters of the wheels B and C, are respectively as five and four, the wheel B must therefore make four revolutions, and the wheel C five revolutions, in order that the same teeth of those wheels shall be in contact and their positions be relatively the same as at the commencement of the movement; if the wheel B does not move, which is the case when the barrel is in action, the wheel C will make four revolutions about the wheel B, in order to arrive at its point of commencement: it will in that course have

made five revolutions about its own axis, and the same teeth will again be brought into contact with each other. Now if the spring contained in the barrel is compleatly relaxed, and that we cause the axis d r, and consequently the wheel B to make eight revolutions in the direction indicated by the dart in the figure, we shall then obtain the maximum action of the spring; it will act to impede any farther revolution of the axis r d; we will suppose the lower figure represented in the plate to exhibit in plano, the relative position of the wheels B and C at that moment; if the distance d e be divided into two equal parts in i, and the semicircle d f e be described on that point, it is evident that in order to produce the intended effect to the greatest possible advantage, the stops should fall into contact in some part of the semicircle d f e; but when the motion of the wheel B ceases, the wheel C is made to commence its motion by the action of the barrel, and imagining the diameters of C and B to be respectively represented by n′ and n, C cannot return to its first position after n′ revolutions about B, because it will previously fall in contact with the stops, in whatever part of the semicircular arc the point of contact may be determined; but it will meet them under different angles: this therefore does not produce the end required. It is a necessary condition that the stops shall fall in contact at right angles before the wheel C shall have compleated the number of revolutions represented by n′, about the wheel B. Let f be the required position—it is necessary that the arc a b should be equal to the arc a c, for if the barrel be turned in the contrary direction to that indicated by the dart, the point b will fall in contact with the point C, and when the centre e of the wheel C arrives at g, the angle d e f will equal the angle d g f; and consequently the conditions will be answered: a l is the fourth part of the periphery of B, and a k is the fourth part of the periphery of C; we have therefore

$$a\,h = a\,k = a\,l\,\tfrac{n'}{n},$$

and if we make $a\,h = a\,l\,\frac{n}{n}$, and draw through the point h the line d g equal to d e, and from the point d draw the line d f perpendicular to g e, the intersection of that perpendicular gives the position of the point f, in which the stops p and q must be in contact whatever be the ratio of the diameters of the wheels B and C; in this instance we shall have $a\,h = a\,l\,\frac{4}{5}$, or the angle g d e = 72 de-

grees. The position of the point f being thus determined the two stops p and q will be placed as in the figure. The centre of the wheel C will arrive at the point g before it will have completed the number of revolutions represented by n′, and the action of the watch will be stopped: in order to wind it up, the wheel B must be turned in the direction indicated by the dart; the wheel C will revolve on its axis in the contrary direction, and the stop p will be checked by q, as at the commencement of the action.

In watches of this description there is no exterior indication by which the state of the spring may be known, and they are consequently much exposed to the inconvenience of being unexpectedly stopped, as well as improperly wound up. M. Breguet, the elder, has contrived the following method of exhibiting the required indication:—A screw m n is cut upon the axis r d, and the broad nut s t with bevelled edges, is fitted upon it, one or more arms u project from the upper surface of the barrel, passing through the nut s t and allowing it a free vertical motion. Now when the watch is wound up, the screw is turned, but is not at liberty to alter its vertical position, and since the nut s t cannot revolve horizontally on account of the arms u, which pass through and hold it, it will be compelled to rise vertically, that is to say, on the axis r d, as we have already shewn in our explanation of the action of the nut and screw in the article C 3; but while the watch is in action it is the nut which turns, and it then traverses the same space in an opposite direction; from this there results an alternate rectilinear motion, which is then converted into alternate circular motion by the application of a bent lever a′, b′, c′, d′, whose arms are placed at right angles to each other; the smaller arm c′ d′ of this lever rests upon the bevelled edge of the nut s t; and the longer arm a′ b′ carries to the exterior of the watch an accurate indication of the state of tension of the spring; and this is exhibited on the dial plate by an arc of suitable dimensions.

If the three wheels A, B, and C are of the same diameter, during the time in which A makes one revolution in the direction pointed out by the dart, the second wheel B will make one revolution in the opposite direction, and the third wheel C will also make one revolution, but in the same direction.

We will now suppose the wheel A to be fixed, and the wheels B and C to be

attached to the wheel A by a bar or arm—it is evident that if the arm be made to turn about the centre of the wheel A, when it has completed one revolution, the two wheels B and C, will also have made one revolution, as in the preceding case with respect to the wheel A; for the relative effect will be the same, whether the first wheel A makes one revolution on its axis, or the second and third wheels make a revolution on that point; but in the second case the wheels B and C will participate in the rotatory motion of the arm, an effect which does not take place in the first case. It follows that the wheel B, whose rotation on its axis takes place in the same direction as that of the arm, will have made two turns or revolutions with respect to the distance, but the rotatory movement of the wheel C about its axis is made in an opposite direction; and consequently by the operation of the moveable arm, it will have traversed the circle which the arm describes in its motion about the axis of the wheel A; but it has no movement of rotation on its own axis, and consequently any lines which may be described on its surface in whatever position or direction, will preserve a constant parallelism among themselves.

This arrangement is often applied to the mechanism by which we illustrate the constant parallelism of the earth's axis in its motion through the annual orbit.

The machinery generally used in the manufactories of porcelain, for the purposes of pounding the materials, and reducing them to the impalpable state in which they are required for the subsequent processes, consists, as is familiarly known, of a large horizontal wheel, which is turned either by the application of animal labour, or the action of water; this wheel drives four or six pinions, the axes of which descend vertically, and each is immersed in a circular trough or vessel A A A A, (see the plan of fig. 6, plate 12, and the elevation No. 1.); at the bottom of each vessel is fitted a slab of stone which exactly fills the space. A second stone D, is placed upon the first—this is also circular, and its diameter is somewhat more than the radius of the lower stone C; the upper stone D performs the action of a muller: it is fixed on or held to the lower end of the pinion by a cramp-iron e d, b c; plates or slabs of porcelain are sometimes substituted for these stones, in which case the upper plate D is surcharged or loaded with some heavier body. The earths and materials which are to be subjected to the operation of the machine are placed in the troughs, which are then filled up

with water, and the process commences: when this arrangement has been some time in use it is found that the stones C and D do not wear uniformly—those parts of each of them which are the most remote from the centre of rotation C are considerably worn down; the acting surfaces therefore will be no longer parallel with each other—the parts f n g m h will leave a cavity: in order to remedy this derangement, in some degree, it is usual to fit the cramp-iron e d b c loosely into the upper stone so as to allow it a little shake or motion, that it may fall to fill up the space occasioned by the wear. This is however but a partial remedy—its operation is to prevent the frequent changing of the stones. The muller or upper stone D can never become equally worn, unless every part of its surface traverses equal spaces in equal times; and this can be accomplished only by such an arrangement for its motion as will cause any lines drawn on its surface to preserve a constant parallelism. The mechanism which is the subject of the present article is strictly applicable to this case: the proper arrangement is shewn in the plan, and the elevation, No. 2, of figure 6, plate 12; the vertical axis passes through the cross piece B B, it is supported by the flanch n n, and terminates in the arm c b, placed at right angles to the upper part. From the centre d of the upper stone, a vertical arm d c projects, and passing through a circular aperture in the arm c b, carries at its upper extremity the toothed wheel e; a short pin f h, projects from the middle of the arm c b, and carries at its upper extremity the toothed wheel h, which is at liberty to turn freely on it; a toothed wheel g is fixed on the under side of the cross piece B B, and the axis a b passes and works freely through its centre. The diameter of the three wheels e, h, and g, are equal.

Another extremely simple and practical method for obtaining the required parallelism is this. (See the plan, and the elevation, No. 3, of pl. 6.) A cylindrical arm d e, projects from the centre of the upper stone D, and passes freely through a circular aperture made in the horizontal arm r b of the vertical axis a b. Another point f, is taken on the face of the upper stone D, in the same direction but of somewhat greater length than c d; from the point f, an arm f g projects and passes freely through a circular aperture in the horizontal arm k i of the axis h i, which is supported by the cross piece B B, it is necessary that the two

horizontal arms k i and r b should be of equal length. When the axis a b is turned, the point d of the upper stone describes a circular path on the centre c, the radius of which is equal to the distance d c; the second point f, on the upper stone, will also describe a circle the radius of which f h is equal to d c; these radii will be constantly parallel, and every part of the surface of the upper stone will have the required parallel motion.

Either of these methods would produce the equal wear of every part of the stone D, supposing it to be homogenous and that the lower stone was similarly circumstanced, but unfortunately this is not the case: the effects of the trituration upon the surface of C diminish from the centre towards the periphery, its surface will therefore become concave, but the surface of the upper stone will also alter its figure, and will become convex; we are well persuaded that a considerable advantage would be obtained in the wear of the stones by the adoption of these arrangements.

Subsequent to our organization of this improvement in the machinery used in the operation, of pounding or trituration, M. Joseph Zureda has communicated to us an account of his machine for polishing glass plates, established in the imperial manufactory of St. Petersburgh. In this machine the polishers are guided in their motion by a contrivance precisely similar to that we have just described: the arrangement is shewn in figure 7, plate 12, in which a b c d is a bar of iron, supported by five cranks e, e, e, e, e, of equal lengths, and are so arranged as to preserve parallelism among themselves, while the centre crank moves about its own axis by communication with the first mover, which in this machine is an hydraulic wheel. It will be easily conceived that by the action of this movement every part of the bar a, b, c, d, will describe a circle whose radius will be equal to the length of the crank arm. This action allows the weight to be lightened by suspending it by the ropes s s.

The polishing tools f f f operate on the surface of the plates, and their position, or that of the plates are altered at pleasure as the state of the process may require.

B 8. Plate 5.

The same problem is resolved by this arrangement, by means of an endless

rope or chain: the movement takes place in the same, or in a different direction, according to the arrangement of the rope on the wheels, whether passing over them without crossing, or being crossed between them.

The length of chains or cords is subject to continual variation from natural causes: the preservation of their uniform tension therefore requires the application of counter-acting weights or springs; but in applying such remedial contrivances, care must be taken that the power shall act in the same direction as the first mover, that is to say, that the tension produced, shall act on the wheel which receives the action of the mover in the same direction as the mover itself; a counterpoising weight may be employed with good effect under such regulation, and may be applied with success to any machine; but if the tension produced by its operation acted in a contrary direction to the motion communicated by the moving power, the effect would be destroyed.

The forms of chains vary according to the purposes to which they are applied; a detached account of several may be seen in the French "Encyclopedie," under the head—Chain-making; and in Les Annales des Arts et Manufactures: No. 41, page 213, we find a description of a chain invented by M. Hancock.

C 8.

In this figure are combined different methods of communicating the motion of wheels in the processes of the arts.

D 8.

This figure shews an endless screw, which transmits its direct circular motion to a wheel. The action of the mover is perpendicular to that of the wheel; the practical applications of this movement are extremely numerous and familiarly known.

E 8.

The silk-mill of Piedmont, presents a remarkable specimen of the application of the endless screw—the screw is in that machine of unusually large diameter. In the figure, A B represents the diameter, and the single thread of which it is composed is divided into six equal parts, which are arranged between the two parallel planes of the figure; these separated portions of the spiral arranged in

echelon upon the periphery of the wheel, are represented in the figure by the double curved lines a b, a b, a b, the rotation of the wheel causes them to act in succession on the cylinders H of the machine, by means of the six rollers or teeth d e, d e, &c. fixed on their peripheries.

A detailed description of this machine may be found in La description des arts et Métiers, published by the academy of sciences.

F 8.

The same problem may also be resolved by the means of bevel wheels, represented in the figure by the truncated cones A and B. This mechanism is of frequent application in the arts, the figure shews a familiar instance, in the common carpenter's wimble. The theoretical principle of bevel wheels may be found in M. Hatchette's work entitled "Traité élementaire des machines."

C 8.

In this figure, A and B are two wheels whose planes are at right angles with each other, they are put in communication by means of an endless rope, which after passing round the horizontal wheel B is conducted by the vertical fixed pulley to the vertical wheel A. The wheel B may have rectilinear motion along the bar a b, revolving on its axis at the same time; in which case the motion should be considered as belonging to Section 17; but if this change of position of B be prevented, it will then arrange itself in this paragraph. This contrivance is adopted in our cotton spinning machinery.

H 8.

Let A B and C D be two parallel axes on each of which is placed three toothed wheels a, b, c, and a′, b′, c′; the wheels a and a′ situated at the opposite extremities of the two axes, are of equal diameter, the wheels c and c′ which are also situated at the opposite extremities of the axes, are of equal diameter, b and b′ the middle wheels on each of the axes are also of equal diameter; the wheels of the axis A B are fixed to that axis, but those of the axis C D are fitted so as to be capable of turning with considerable friction, and

any one or more of these may be firmly attached to the axis (C D) by the arrangements described in the article I 7′ or K 7′; this being understood, it will be evident that we may produce the rotation of the axis C D with the same velocity as that of the axis A B, by throwing the wheel b into action; its velocity will be greater than that of A B, if the wheel a be placed in action; and if the wheel c is put in action its velocity will be less than that of A B.

I 8.

Let A B, C D and E F represent three parallel axes; each of which carries two toothed wheels a and b; we will also suppose the moving power to be applied to the axis A B; the wheels a b of the axis A B are fixed to that axis; the wheels of the axes C D and E F are set upon them and are at liberty to revolve with considerable friction, but they may respectively be attached to their axes by the methods I 7′, K 7′; the wheels a a a are of equal diameter, and the wheels b b b are also of equal diameter, but the diameters of the latter are double those of the former. This arrangement is capable of four different combinations.

1. If the two wheels b b of the axes C D and E F are placed in action with the small wheel a of the axis A B, the axes C D and E F will revolve in the same direction, and in a contrary direction to that of the mover, with the same velocity, which will be equal to half that of the mover of the axis A B.

2. If the wheels a and a of the axes C D and E F are placed in action with the wheel b of the axis A B, C D and E F will revolve in the same direction, and with equal velocities, being double that of the mover.

3. If the wheel b of the axis C D be placed in action with the wheel a of the axis a b, and the wheel b of the axis a b with the wheel a of E F, the axes C D and E F will revolve in the same direction, and the velocities of the axes A B, C D, and E F, will be respectively as 2, 1 and 4.

4. If the wheel a of the axis C D be placed in action with the wheel b of the axis A B, and the wheel a of A B with b of E F, the axes C D and E F will revolve in the same direction, and the velocities of A B, C D and E F will be respectively as 2, 4 and 1.

K 8. Plate 6.

To convert direct and uniform circular motion, into variable circular motion, the velocity of which shall vary by a given law.

IN this figure we have a plan and an elevation of the same parts, each part being respectively distinguished by the same letter of reference.

If the axis D be required to perform a certain number of revolutions, as *n*, while another, C, performs one revolution, with variable velocity, it will be evident that any two points of the axes should return to the same positions after the axe D shall have performed the number of revolutions expressed by *n*, or the axis C have performed one revolution. It will follow that these points will traverse equal spaces during *n* revolutions of D, or one revolution of C.

In order to simplify the application, we will suppose the two axes C and D each to perform one revolution in the same time; this example being clearly understood, all others will become perfectly easy of comprehension.

Let P Q, and M N represent the axes of two wheels, a b C, a d D, two toothed segments of unequal radius and equal arcs, and arranged on the level of the line 1, 1; (see the elevation) b′ e f C, and d′ n m D are toothed segments of equal radius and equal arcs, and arranged on the level of the line 2, 2; q C p, q D r are also two toothed segments respectively equal to the segments a D d and a b C, but arranged at the level of the line 3, 3.

It will be seen that by this arrangement the velocities may be varied by fixed intervals and in any required manner, observing that the points a a, are brought into contact, when the axis M N has completed the number of revolutions expressed by *n*.

This piece of mechanism is somewhat difficult of construction, from the interchange of the working parts at each alteration in the velocity, these difficulties may however be practically lessened, by encreasing the number of the teeth in the arcs, in cases where the effective action of the arcs is not produced with

sufficient facility and certainty, it may be assisted by applying the additional power of a spring or weight.

The solution of this problem may also be obtained by means of two truncated cones A and B (figure K′ of the same compartment of plate 6) of equal dimensions placed as represented in the figure, at a small distance from each other, with their axes parallel, the lesser diameter of A placed upwards, the lesser diameter of B placed downwards, and the lesser diameter of A, at the same height as the larger diameter of B. On the convex surface of each of these conical frustums is formed an helical groove, one extremity of a rope n m is attached to the larger diameter of B at the point of commencement of the spiral groove of that cone, and after following the entire course of that spiral, it is attached by its other extremity to the corresponding point on the larger diameter of the cone A. It is evident that if A revolves in the proper direction with an uniform velocity, B will revolve also, but with a varying and decreasing velocity, being at first greater than that of A, in the middle part of its course equal to it, and towards the end of its course, as much less than A as it was greater at the commencement: the rope n m, will then be entirely coiled on the surface or groove of A. The movement cannot be continued in the same direction.

If, instead of cutting spiral grooves on the surfaces of the frustums A and B, they were left of their original conical figure, and an endless rope substituted for the rope n m, which shall pass round them, it will be evident that such a cord may be applied to the cones at any required height, without the necessity of altering its length. Suppose this endless rope were first placed on the lower parts of the cones, the uniform rotation of A will communicate a like motion to B, but the velocity of which will be greater than that of A in a known ratio, and this movement may be continued at pleasure ; as the situation of the endless rope is shifted towards the upper part of the frustums, the ratio of the velocities decreases, when it arrives at the middle of the height, the velocities become equal, and increase as it approaches the upper ends. The mechanism is used with great success in England, for the purpose of regulating the velocities of direct circular motion, particularly in the machinery used in the potteries, and manufactories of porcelain. In these arrangements the endless rope

is made to traverse on the cones by a rack movement which is placed between them and parallel to their axes, and guides the rope. The contrivance is extremely simple, and produces the required change of velocity in an instantaneous manner.

L 8.

The upper figure in this compartment of the plates represents an elevation of the subject, and the lower a plan; if we suppose the motion of either of the axes M N, P Q of the preceding figure to be equable, the motion of the other may be either retarded or accelerated equably. This has been effected by M. Roëmer of the Royal Academy of Sciences, in the construction of a wheel whose motion exhibits and explains the unequal velocity of planetary motion. See Machines approuvées par l'Académie; vol. i. No. 24.

The inventor proposes a conical pinion cut through its whole length, as represented in the upper figure: its teeth work with those of a conical wheel B, the teeth of which are spirally disposed as a b c in the plan of the figure: the varying form, dimensions, and position of these teeth as they descend the spiral, is of course to be determined by the form, dimensions, &c. of that portion of the pinion with which they are respectively to act.

M 8.

In this figure, the upper is an elevation of the subject, the lower the plan.

Let A represent a drum wheel; B a truncated cone, the surface of which is cut into a spiral path from the base to the summit of the frustum, and a b c is a rope of which the extremity a is attached to the cone; near to its lesser base, the rope is coiled upon the spiral, and its other end is attached to the surface of the drum wheel at C; the equable rotatory motion of the drum will produce a variable rotatory motion of the frustum; and if the frustum be made to revolve with an equable velocity, the rotation of the drum will reciprocally be of variable velocity.

In watch-making, the mover employed is a spring enclosed in the drum A, which is called the barrel or cylinder, the truncated cone B is termed the fusee; the chain,

which is attached to the barrel and the fusee, is wound up on the latter, whose property of equalizing the action of the spring is derived from the unequal diameter of its spiral.

Watch-makers are enabled by means of a balance or spring, to suit the fusee to the action of any given spring.

In the Theatrum Machinarum of Leupold, vol. i, plate 48, we find descriptions of various machines for the purpose of measuring the force of the wind: the first is simply a sail or vertical frame placed upon a carriage—this is placed upon a horizontal plane, at one end of which is an horizontal axis carrying a drum wheel and fusee. A rope attached to the carriage passes over a simple fixed pulley set at one end of the plane, and after making two or three turns on the drum wheel, is attached to it; another rope is attached to that point of the fusee which is nearest to the axis of rotation, and is then stretched by the action of a weight; the whole is then arranged so that the frame or carriage being placed close to the edge of the plane or table, the weight whose action produces the rotation of the axis, shall be in equilibrium with the friction of the carriage with the plane on which it moves. If the apparatus be now placed so that the wind shall act at right angles to the sail the carriage will run the entire length of the plane; but when this movement takes place, the drum makes a rotation on its axis, and the rope, which sustains the weight, is coiled on the fusee, a complete equilibrium will therefore take place, and then the radius of the fusee at that point which is last touched by the rope, will express the force of the wind; all the machines shewn by this author are founded on the same principle.

N 8.

A B represents a fixed beam or plank, having a mortice n m cut through it, and in which is set the axis of a toothed wheel C; a curved spring is applied between the centre of this wheel and the end A of the beam, so as to give it a constant tendency towards the point A; D is an elliptical wheel of which the periphery is toothed. The equable circular motion of C will communicate to the wheel D a circular motion of variable velocity. This method involves the same practical difficulties noticed in the articles K 8 and L 8; the correct action

of these wheels can in strictness only take place when the teeth are supposed to be infinitely small; the teeth of the wheels may however be dispensed with, and an endless rope substituted for them, which has a small degree of elasticity, or which has its tension encreased by means of a weight or spring: paying due attention to the observations made in the article B 8 upon the proper method of applying them.

O 8.

Is an universal joint which is used for the purpose of changing the direction of circular motion: it is frequently applied in the adjustments and motions of astronomical instruments, when it is required to communicate a circular motion to a distant point, and in a new direction.

A very ingenious application of this movement has been made by Messrs. de Bettancourt and Bregnet to their telegraph at those points where the line of communication alters its direction; in a memoir presented to the National Institute, they have shewn that if the rotation of oue of the two axes is equable, that of the other will be variable; and the ratio of the velocities will be the same as that which subsists between the actual subtense of the angles formed on a circle perpendicular to the axis of the first, by radii which divide the circumference into a certain number of equal parts, and the apparent subtense of the same angles, to an observer situated at a great distance, and in a parallel direction to the second axis. An acquaintance with this property is extremely useful in calculating the difference of the resistance which takes place in this movement, and especially when conducted on a large scale; an instance of this occurs in the application of the principles to the purpose of changing the inclination of two Archimedian screws used for draining, and which are worked by the power of wind.

An application of the universal joint has been made to the construction of a flatting engine by M. Droz.

The description of Wright's sowing or dibbling machine, in which this mechanism is employed, may be seen in the Repertory of Arts and Manufactures, vol. xv, page 369.

The reader may also consult Technica curiosa sive Mirabiliæ Artis of Gaspar Scholt, 1664, page 664.

P 8.

Let A B represent an axis the continuity of which is broken by some impenetrable obstacle, and the separated portions of which are required to make their respective rotatory movements simultaneously, or as if composed of an entire piece. To each separate portion A and B of the axis, is fixed a wheel, as E and F, these are of equal diameter: an entire axis N M, is fixed near A B, parallel to it, and at a distance from it equal to the distance of the wheels E and F; upon this axis are cut the grooves C and D, at right angles to the axis, their distance is equal to the distance of the wheels E and F upon the axis A B, two endless ropes or bands pass respectively over the wheels E F, and their corresponding grooves C and D: the two bands must be disposed in the same manner, that is to say, either both direct, or both crossed, so that the motion of M N may be transmitted to A and B in the same direction, which would not be the case if the bands were arranged dissimilarly, the two portions of A and B would then move in opposite directions.

Q 8.

Practical mechanics employ a variety of methods for regulating the unforeseen inequalities of the moving power, as well as to protect the machinery, and the persons employed in its management from the serious accidents to which they are exposed by abrupt changes in any part of the acting power. The application of the fusee in the construction of the common watch to the purpose of equalizing the action of the spring, is familiarly known, as well as the methods adopted to compensate the variations of length in the pendulum, from the changes of temperature, and to render the vibrations of the balance isochronous: the use of a fan wheel in clock movements to regulate the action of the moving power is also well known, and the adoption of the same mechanism in other machinery. In our article N 7′, we have shewn the methods in general use in steam engines for regulating the action of the steam. In machinery where human labour is applied as a first mover, as for instance, in some of those machines which are

seen in all ports and harbours, whether for the purpose of cleansing them, or as cranes for raising and lowering considerable weights, in case of the rope breaking the operators would be greatly exposed to danger, but for the expedient usually adopted of a long beam or spring applied as a curb upon the periphery of the wheel; the friction thus produced quickly obviates the danger and inconvenience to be expected from such derangement, and compleatly relieves the operators from apprehension of danger, as has been before noticed page 49.

M. Breguet has adopted a piece of mechanism which he intends to effect an approximating equalization of the action of a first mover in pendulum movements, by encreasing the friction in proportion as the moving power is augmented; this contrivance we consider to be judiciously applicable to other purposes. It consists of three wheels A B C, which are set upon the plate E E E E′, of two pinions, and an arm D; the centre of the movement, which is variable at pleasure, is in E′; the arm carries at the point D a pivot of the wheel B, and rests upon a cylindrical portion upon the face of the wheel C.

Suppose the wheel A to be moved in the direction of the dart shewn in the figure, by a variable power, such as that of a spring—the action of the wheel A upon the pinion of B will then be as the power operating upon A; but as the pinion of B is carried by the piece D, its tendency is in the direction of B, and resting with its end on the cylindrical portion of C, the friction of the latter on its pivot is considerably encreased, which will tend to diminish any excessive action of the wheel C.

R 8.

In this figure we have a plan, and an elevation of the arrangement, in which as usual, the same parts are respectively marked with the same letters of reference.

A and B are two wheels of different diameters, as depicted in the figures: they are each fitted by friction only upon an axis common to both, and which has no rotatory motion; and they are arranged at a small distance from each other. The wheel A is grooved on the edge for the purpose of receiving an endless rope or band; the wheel B is also grooved on its edge, and has a certain number

of projecting pieces on its upper surface which compose a series of other wheels of different diameters, and their edges are also grooved.

Two smaller wheels C, are placed upon an axis situated perpendicular to the surface of the wheels A and B; the diameter of these wheels is equal to the difference of the radius of A and B; and they are so arranged upon the axis that one of them may work with the wheel A, and the other with the wheel B; the combination and the particular arrangements of this wheel-work is arbitrary, and will therefore depend on local circumstances and the judgement of the constructor.

The arm e f terminates in two rings: the common axis of the wheels A and B passes through one of these rings with friction, and the common axes of the wheels C also pass through the other ring in the same manner; the axis of the wheels C is therefore constantly parallel to and equi-distant from the axis of A and B.

D is a cylinder to which the moving power communicates a direct circular motion. Two parallel wheels and endless bands transmit that motion to the wheels A and B, their rotation is in contrary directions, one band passing directly from D, the other being crossed.

S 8. Plate 11.

We will now suppose the wheels A and B of the last example, to be of equal diameter; and that for the two wheels C, we substitute a single wheel which is placed at right angles to the faces of A and B; in short, that A B and C are bevel wheels, which are arranged and combined as in the figure. The wheel C is fitted easily on the axis r s e, and the axis D E passes through r s e by a cylindrical opening for that purpose at s; the wheels A B and C are kept in their respective positions upon their axes by collars, or similar fittings, which prevent them from sliding upon the axes.

The wheel C has two rotatory motions—one about its axis r s, the other about the transverse axis D E.

A ring r u e m, may be attached to the axis r s e, having its plane parallel to to that of the wheels A and B, as in the figure; the exterior edge of the ring may be circular or of any required form, or which circumstances may require,

and by this means a circular movement may be converted into alternate recti-linear movement, with any required modification of velocity or direction.

This piece of mechanism is extremely simple of construction, is practicable on a scale of reduced dimensions, and is capable of numerous useful applications, of which we shall give selected examples.

SECTION IX.

To convert direct circular motion, of uniform velocity, or which varies by a given law, into alternate circular motion, of velocity either equable, or variable by a given law, and in the same, or in different directions.

THE arrangements, shewn in the articles E 7, U 7, B 7′, E 7′, G 7′, H 7′, I 7′, K 7′, L 7′, M7′, may also be considered as examples of the required conversion.

A 9.

A is a wheel with waved teeth, and which communicates an alternate circular movement to the bent lever P S R. The method of constructing these curved teeth may be seen in the memoir of M. Deparcieux, to the Academy of Sciences, which we have already mentioned. There is no reciprocal action in this piece of mechanism.

B 9.

This is a remarkable instance of the preceding example, in which there is but one wave or curve. An application of it may be found in the Repertory of Arts and Manufactures, vol. iii, page 220; in the specification of a patent granted to William Fulton, &c. for a method of working pumps; and in Les Annales des Arts et Manufactures, vol. xxii, page 325.

A groove of this figure may be described on the surface of a cylinder, and if the extremities of two levers be introduced to it, an alternate motion may then be transmitted to four pumps at once, under an arrangement by which two of them shall be elevated while the other two shall be depressed.

In Leupold's work—Theatrum Machinarum Hydraulicarum, vol. i, we find an application of this contrivance to the raising water by means of two buckets. He places the mechanism shewn in B 9, near the upper extremity of a vertical axis, which turns constantly in the same direction, by the action of a fall of water upon the float-boards of an horizontal water wheel. A piece of wood placed vertically in the prolongation of the axis, supports a long horizontal beam, which presents the precise appearance of a balance, of which the supporting vertical piece will represent the suspension, and the horizontal beam the arms. The beam carries a bucket at each extremity, and is supported upon the mechanism exhibited in the article B 9, by friction rollers. The rotation of the shaft of the water wheel will communicate an oscillatory movement to the horizontal arm, and the two buckets will, by their alternate action, raise the water from a reservoir to an higher level.

C 9.

In this figure we have an elevation of the subject in the upper figure, and a plan in the lower figure, with corresponding letters of reference.

The memoir of M. Deparcieux (see A 7) furnishes the methods of describing a curve a m n p, which is grooved, and fixed to a lever A B which is at liberty to turn freely upon an axis which passes through its extremity A; if we suppose 1. That the wheel M has an equable rotatory motion on its centre, 2.—That the pin p fixed to a point on the surface of the wheel M, shall work in the groove which forms the curve a m n p, this curve may be of such a figure that the lever A B shall make oscillations which will fulfil one of the following conditions:—1. That the arcs described by any point of the bar A B, shall be described with an equable velocity; 2.—That the velocity shall vary by a given law; 3.—That it shall not be the arc itself, but rather the chord of that arc which shall traverse with an equable velocity, or varying by a given law.

The curve described in the present figure, is of a nature to satisfy the first of these three conditions.

D 9.

We have in this figure also a plan and elevation of the subject, with their corresponding letters of reference.

The curve a m n p may also be fixed on the surface of the wheel M, and in such a manner that the equable circular motion of the wheel M shall communicate to the lever A B an oscillatory movement which may fulfil one of the three conditions stated in the foregoing example, by means of a pin p fixed in the lever, and which acts in the groove of the curve a m n p. The subject of that, and the preceding article, are capable of various useful applications in the solution of a great number of curious problems.

If the alternate circular motion of the lever be considered, all such motions will be arranged in this place; but if a grooved bar be fixed on the chord of the described arc, the intersection of that groove, with a longitudinal groove made in the lever, will present an open space in which a point may be inserted which shall have an alternate rectilinear movement; and in this case, the two motions C 9 and D 9 will be classed in Section 7. The same will be the case if the movement be that of a weight suspended from the extremity of a bar, by means of a rope which passes over a fixed pulley. Lastly, if an alternate circular movement be communicated to the wheel M, the same motions will then be arranged in the 17th and 19th Sections.

The movement D 9 has been applied to the construction of a watch escapement by M. Volet. (Machines approuvées par l'Academie Royale, Vol. vii. No. 450.)

E 9.

A cylinder A furnished with cams or curved projecting pieces, has a movement of rotation on its axis, and operates to raise the hammer B, which is suspended on an axis at C. This motion is too well known to need many illustrative examples.

F 9.

The upper of these figures is an elevation of the subject, the lower a plan, with the same letters of reference to each figure.

This gives an inverse solution of the problem in Section IX. A is the lower extremity of the shaft of a large wheel or fly, on which is fixed the ratchet wheel

B. C C is a wheel fitted on the shaft of the fly, by its friction, and carries a click-piece q, which acts upon the ratchet wheel by means of a spring.

The alternate circular motion of the wheel C transmits to the fly and the shaft A a direct circular motion in the same direction; but the wheel C will only act during the half of its oscillation. An application of this motion by White, may be seen in the report of Messrs. Prony and Molard, adverted to at H 7.

G 9.

This is another application of the movement described in the preceding article, P Q is a lever having an alternate circular motion, which it communicates to the wheel C, by means of the rope a b c d e, the proper tension of the rope is produced by the weight P, or by a spring. The wheel C is fitted on the axis A of the fly-wheel N, by its friction only; on the end of the axis of the fly-wheel is fixed a ratchet wheel shewn in the figure, and in which the click-piece α acts, the click being fixed on the wheel C. Under this arrangement, the alternate circular motion of C will cause the fly-wheel N to revolve constantly in the same direction.

An application of this movement is described in the " Bibliothéque Britanique," vol. vi, article " Arts," in an account of a patent granted to T. Bingen, for a method of producing a rotatory motion, by the action of an alternate movement in any direction, and which may be afforded by the power of steam or any other principle. The editor subjoins some observations on fly-wheels.

H 9. Plate 7.

A B is a lever which is capable of an alternate circular motion about the axis C: c d is an arm which has a free motion on its extremity c; its other extremity d is fixed to the toothed wheel E, which works with a similar wheel F set on the axis of the fly-wheel N; on the reverse side of the wheels E and F, is an arm e f which preserves the constant distance of the wheel E from the centre of the fly-wheel; the alternate circular movement of the lever A B elevates and depresses the wheel F, but this could not take place unless the

wheel F revolved on its centre. According to the arrangement of the machine the actual movement may be either direct or alternate; but the inertia of the fly-wheel operates to render it direct and nearly equable: a reciprocal action takes place, when the machine has commenced its movement. This mechanism is adopted in steam engine work—a description of it occurs in Prony's Architecture Hydraulique, part ii, page 118.

It will be observed, that notwithstanding the two wheels E and F are of the same diameter, the fly-wheel N makes two revolutions for each oscillation of the lever, which prevents the necessity of using fly-wheels of the large dimensions required to produce the same effect in the usual construction.

I 9.

The following is a description of a rotatory motion, for which a patent was obtained in England by Edmund Cartwright. This rotatory motion is communicated by steam, and its velocity may be encreased at pleasure, without the assistance of wheel-work.

A B represents the side elevation of the upper part of the framing which incloses the boiler, the cylinder, the fly-wheel, and all the acting parts of the engine; an axis crosses this framing, on which the pulley or wheel C revolves; a chain passes over this wheel and is attached to the upper end T of the piston rod; (the wheel C receives an alternate circular motion by the action of the piston and its counterpoising weight P;) the wheel C carries a lever handle D, which by means of the arm K communicates with the lever F, placed horizontally on the top, or at the side of the boiler. Another axis, which may be placed either above, below or at the side of the first, passes through the fly-wheel G, and carries at its other extremity a lever handle H, which communicates with the horizontal lever F by means of the arm I, as before described of the wheel C by means of the arm K.

It is evident that when the wheel C is made to revolve by the action of the piston T, the arm D which is fixed on its axis, will cause the fly-wheel G to revolve also, the wheels G and C being connected with the same lever F. If C therefore be moved alternately in the direction a b and b a by the action of the

piston, and its counterpoise P; and if the lever D of the wheel C moves in the same direction, the lever H of the fly-wheel will perform the same alternate movement, unless it should be (as it ought) of such length as that at the termination of its arc of rotation, it is at liberty to pass beyond it; which in fact, produces the complete rotation of the fly-wheel.

If the lever D of the wheel C be so disposed, as that when it revolves in any quantity not exceeding one entire revolution, it shall pass from e to a, by f, or in the direction traversed by a given point of the wheel C, then D will cause two vibrations of the lever for one stroke of the piston, and the fly-wheel G will in the same time make two revolutions. Further, if the diameter of C be so determined that it shall complete one revolution and a half for each stroke of the piston, and retrograde the same quantity, the lever F will receive three vibrations for each stroke of the piston rod. Lastly, if the wheel C be of such a diameter that it shall make two direct, and two retrograde revolutions for each stroke of the piston rod, the lever F will then make four vibrations, and the fly-wheel four revolutions.

It thus appears that the fly-wheel may revolve with any given velocity, without the aid of any combination of wheel work.

K 9.

This figure represents the common treadle. If we suppose the lever arm of the fly-wheel to be connected with the end of the lower lever or treadle, by an inflexible arm, the relation between the component parts of the treadle, and the effect or action become determinate, which, in a certain degree, is not the case when the arm is flexible; we will suppose the following data:—1. The length of the lower lever.—2. Its centre of rotation.—3. The value of the arc which it will describe at each oscillation.—4. The position of the centre of the fly-wheel with respect to the centre of rotation of the lower lever, the length of the upper or shorter lever, and that of the longer and inflexible arm, are known quantities. To determine their value, place the treadle or lower lever in its two extreme positions, the higher and the lower points of its vibrations, and draw right lines from the centre of the fly-wheel to the extremity of the treadle in

those two positions. The first of these distances is known, and should be equal to the difference of the length of the inflexible or longer arm, and the upper or shorter lever; the second, which is also a known quantity, should be equal to the sum of those lengths; consequently, the length of the longer arm, which must be more than that of the upper lever, is equal to half the sum of the two distances between the centre of rotation of the fly-wheel and the extremity of the treadle, in its two extreme positions; and the short lever must be equal to half the difference of those distances. If we suppose the angular velocity of the treadle to be equable, the velocity of the fly-wheel will be variable through its whole course; but the inequalities of its motion will become less sensible as the angular measure of the motion of the lower lever or treadle is smaller, and as the distance between the centre of the fly-wheel, and the centre of rotation of the treadle is greater.

L 9.

The conversion of an equable circular motion into an alternate circular motion whose velocity shall be variable according to a given law, is a problem which has engaged much attention in the fabrication of time keepers. The following example is selected from the Machines approuvées par l'Academie, Vol. iv. No. 267.

"A clock motion which shews true time, invented by the curate of St. Cyr."

"The annual wheel A carries a curve of equation B C D; upon the face of this curve is cut a groove parallel to its edges; in the groove, moves a stud E fixed on the piece E F, and moveable on the point F; the stud is also fixed to a second piece E G, this is attached to the cylinder H, which carries the minute hand I, so that it follows the variations of the curve more than half the circumference of the minute dial; which is sufficient to mark the inequalities indicating the equation."

Descriptions of other pieces of mechanism for the resolution of the same problem, may be seen in the following memoirs, contained in the Recueil des Machines approuvées par l'Academie des Sciences.

Clock which shews the true time, invented by Le Bon, Vol. iii. No. 146.

A clock motion, which shews the true time, by the same author, Vol iv. No. 235.

Clock, which shews the true time, invented by M. Kriegleissen, Vol. iv. No. 269.

A clock motion, which shews the true and mean time, by Thiout, Vol. iv. No. 278.

An equatorial watch, invented by Dutertre, Vol. vii. No. 453.

An equatorial clock, invented by Ferdinand Berthoud, Vol. vii. No. 488.

Another clock is described in the seventh volume, No. 495.

M 9.

The following is the mechanism adopted by M. Breguet in an equatorial clock.

It may be considered as composed of two parts—one of them fixed, the other moveable.

The fixed portion of the arrangement is the square plate A A A A, held by four screws; it is cut through or grooved in the form of the curve of equation.

The moveable portion is composed of a plate g g, having its centre of motion in a; it carries a moveable tail-piece which has its centre of motion in b; one of its two extremities c, acts against the edge of the curve; the other extremity d, applies to the continuation e of an index or needle f, which has the same centre of rotation as the plate g g. The continuation of the index f is pressed into its action on the tail d by means of a spring h, the fixed extremity of which is screwed to one extremity of the plate g g as in the figure; the index J is fixed on the same axis as the index f and is concentric with it, or moves on the same centre of rotation.

The plate g g performs a complete rotation on its centre of motion a in one year; and, as we have described, carries with it in its course all the moveable parts of the machine. It will be conceived that the index J, which is fixed to the plate g g, might point out the days of the year by being set on a dial divided into 365 equal parts, and the index might be expected to traverse equal spaces upon these divisions in equal times, which however will not be the case. When the lever c acts on that part of the curve which is farthest from the centre, as I, the index J will be several divisions in advance of the index f; but on the con-

trary, when the lever acts on the part M of the curve which is nearest to the centre, the index f will then precede the index J by a certain number of divisions.

This difference of motion between the two indices is produced by the action of the lever c b d upon the plate AAAA, and the construction of the curve is calculated to advance or retard the index f relatively to the index J, by a quantity of the arc, or a number of divisions equal to the difference between the true and mean time in minutes, on the day indicated by the index J.

N 9.

The subject of this figure is a ratchet lever: it is the invention of M. de la Garousse; the description of it is extracted from the account of "Machines approuvées par l'Academie des Sciences," Vol. ii, No. 74. In this machine an alternate circular motion is converted into direct circular motion, without reciprocal action.

The hooked arms I L, M N, are moveable on the points I M, and are so disposed that the lever by its alternate and direct motion, causes one of them to draw the ratchet wheel constantly towards it, while the other quits the tooth which it had acted on, and applies itself to another.

The inventor has applied his lever to a machine for communicating a simultaneous action to four corn mills. Vol. ii, No. 121.

See also figure 1, plate 26 of the first volume of—Theatrum Machinarum de Leupold.

O 9.

This mechanism is a wheel lever, invented by M. de la Garousse; see Machines approuvées par l'Academie, Vol. ii, No. 72. It is a modification of the preceding contrivance.

The large lever AB has its fulcrum in C; above and below are two short arms D and E, each moveable on its centre pin; and each of them also applies to one of the spindles of the lantern wheel F.

The alternate circular motion of the great lever produces the direct circular

motion of the wheel F, on the spindles of which the arms D and E act in rotation. If a rope were coiled on the axis of the wheel F, a direct rectilinear motion would be produced, and the arrangement would consequently belong to Sec. 4.

P 9.

In this machine, a b is a kind of pendulum or long lever handle attached to an horizontal cylinder R, which operates to give it an alternate circular movement; the two click-pieces o n, p k are fixed upon its convex surface and near its extremities by hinges, and they act upon the opposite teeth of the horizontal ratchet wheel S T, communicating to it a direct circular movement while the action of the moving power is uninterrupted.

In Vol. v. No. 209 of Machines approuvées par l'Academie des Sciences, we find an application of this movement to the construction of a machine for drawing loads, by M. Alix.

Q 9.

This machine is a modification of the lever of M. de la Garousse, (O 9.) but is not of equal merit—the power not being constant in its action.

This contrivance has been proposed for raising weights, by M. Henry. See Machines approuvées par l'Academie, Vol. iv, No. 264.

Several different arrangements of levers upon this plan may be seen in the first volume of—L'Architecture Hydraulique de M. Bélidor, ; and in the—Theatrum Machinarum de Leupold.

R 9.

A is a horizontal wheel toothed on its upper face through a little less than one half of its periphery; B and C are two toothed wheels fixed to the axis d e; their distance should be equal to the diameter of the wheel A. It is evident that the toothed portion of the wheel A, which must always be less than its semi-periphery, will fall into action with the wheels B and C alternately, and communicate an alternate circular motion to the axis d e.

In Bockler's work (see E 3 and K 3) fig. 109, we find this arrangement applied to the working of pumps. He first communicates the direct circular motion of

the horizontal shaft of a vertical water wheel to a vertical axis, and then converts the motion of the vertical axis, into an alternate circular motion upon another horizontal axis by the contrivance we have described in the present article: and lastly, the alternate circular motion of that horizontal axis communicates a vertical and alternate rectilinear motion to the piston rods of four pumps: two of which are made to rise, while the other two descend, and this by the mechanism described in our article M 17; the pump rods have racks upon them, and the horizontal axis has pinions or toothed wheels.

In Ramelli's work (referred to in our article A 7′) may be seen an application of this contrivance to the action of two pumps.

If the wheels B and C were indented on a portion of their inner faces, and the wheel A were toothed over its entire periphery, and were placed between the edges of the wheels B and C, it will be evident that the direct circular motion of the axis d e will produce an alternate circular motion on the axis of the wheel A.

Bevel wheels may be introduced in the arrangements of this piece of mechanism although we have given no representation of such an application in our figure.

Ramelli, in the work above mentioned, shews several applications of this last method, which is, in fact, but a modification of the arrangement first described in this article.

OBSERVATIONS.

In all mechanical combinations for the measurement of time, the moving power, or sustaining force communicates a direct rotatory motion to each wheel of the train. To render this movement uniform, notwithstanding the irregularities which must necessarily affect all mechanical arrangements of great delicacy, whether arising from the moving power—the imperfection of workmanship—the influence of temperature—or from other accidental sources, the last wheel of the train, or scape-wheel, has been placed in contact with the regulator; that is to say—with the pendulum or balance, of the clock or watch. This regulator makes an alternate circular motion, which in the present state of perfection of the art, possesses the property of performing its oscillations in equal times, of

whatever extent those oscillations may be, or under whatever temperature they may be performed. These valuable properties are afforded by various methods of construction, of great ingenuity and intelligence; but the particular consideration of which does not come within our present purpose.

The communication between the direct circular motion of the scape-wheel, and the alternate circular motion of the regulator, is effected by a piece of mechanism technically termed the escapement; its functions are to maintain the action of the sustaining force on the regulator against the loss which it suffers at each vibration from friction and the resistance of the air, and to communicate the equable action of the regulator to the train-of wheels*.

All the known escapements may be arranged in four distinct classes. viz.

1. The escapements of recoil.
2. The dead-beat escapements.
3. The free vibration escapements.
4. The free vibration, and remontoire escapements.

The recoil escapements are those in which the scape-wheel acts constantly on the regulator, by its alternate action on two pallets; these are impelled in turn by the teeth of the wheel, and the regulator continuing its vibration produces the retrograde motion of the wheel.

The recoil escapements may also be arranged under three distinct heads, viz.

1. The crown-wheel escapement †.
2. The anchor or crutch escapement ‡.
3. The double lever escapement §.

The dead-beat escapements are those in which the teeth of the wheel, after escaping from the pallet or impelling lever, fall on a circular plane, or on a portion of a cylinder carried by the regulator, the motion of which continuing, the tooth remains at rest. There are two descriptions of these escapements, one

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* Histoire de la mesure du temps par les Horloges, par Berthoud, vol. ii, page 303.

† Essai sur l'horlogerie, par Berthoud, 1786, vol. i, page 136.

‡ Idem, vol. i, page 139.

§ Idem, vol. i, page 138.

which is properly the dead-beat escapement, and is adopted in clock-making; another which is termed the cylinder escapement, and is applied in the construction of watches.

The free vibration escapement is also a dead-beat escapement, the wheel being at rest after the impulsion; but the repose of the wheel, in this instance, differs from that of the escapements above mentioned, in as much as the wheel after its impulsion, neither comes into contact with, nor rests upon the cylinder carried by the regulator; but is checked by a piece which is separate from that portion, so that the regulator completes its vibration freely, without experiencing any resistance from the escapement.

The free remontoire escapement * differs essentially from all others, either of those adopted in clock-making, or those used in the construction of watches: in all these escapements, the action of the scape wheel is directed immediately on the regulator, communicating to it the sustaining force which it has itself received from the train and the mover, without modification; so that this force cannot be considered as perfectly equable, from the irregularities of the wheel-work, the friction of the pivot, and of the sustaining force itself. In the free remontoire escapement the scape-wheel does not act directly on the regulator, but at each vibration coils a spring into a given position, or to a determined point of tension; and which at its return, restores to the balance the necessary sustaining force: whence it results that the power exerted being equable, and communicated to the balance, the latter will describe equal arcs in equal times. This invention takes its date from the commencement of the 17th century.

We shall not attempt to detail or describe all the escapements which have been invented; and still less to constitute ourselves judges of their merit. We shall confine ourselves to the giving a few examples in each of the four classes above mentioned: those who may wish for more extensive information on the subject, may beneficially consult the elaborate work of M. Berthoud from which valuable source we extract the following accounts.—

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* Histoire de la mesure du temps, vol. ii, page 44.

S 9.

The crown-wheel escapement.

The scape-wheel I I′ receives from the moving power a direct circular motion in the direction I S I′ S′, (so that the perpendicular sides of the ratchet teeth precede in the progress of the wheel) and it transmits this motion to the levers or pallets h i, which are carried by the verge or vertical axis K K, which is also the axis of the balance.

The alternate motion, or vibration of the balance is here produced by the action of the wheel I I′ upon the pallets of the axis of the balance; they are set at an angle of about 90 degrees with each other, so that when the pallet h is impelled by one tooth of the wheel, and has escaped, the other pallet i is presented to a tooth of the wheel diametrically opposite,and is impelled in its turn; the wheel turning constantly in the same direction, the balance vibrates on itself, and by its alternate vibrations regulates the velocity of the wheel I, and consequently the action of the whole train.

This balance differs materially from those we term regulators, which possess the property of making isochronous vibrations.

An improvement of this escapement was made by M. Huygens in 1675, by the application of the spring to the balance (a discovery which Leibnitz awards to M. Huygens.) The intention of this alteration was to produce several revolutions of the balance for each vibration; for which purpose he converted the balance into a toothed wheel, working with a pinion set on the axis of the balance.

In the works of Rosbery and Bockler, already mentioned in our article K 3, we find the description of several mills, in which a weight is the moving power; and whose action is regulated by a contrivance similar to that here described.

T 9.

The dead-beat escapement for seconds pendulums in clocks, constructed by Graham.

This escapement does not materially differ from the recoil anchor escapement invented by Clement, a clock-maker of London, in 1680.

The piece which forms the escapement has also the anchor form; but with this difference—that the pallets are so constructed as to produce no recoil: this becomes what is termed a dead-beat escapement, by means of circular or cylindrical faces which are formed on the pallets, and correspond with the inclined surfaces which produce the maintaining power of the pendulum. The Traité de Thiout, page 93—and l'Essai sur l'Horlogerie de Berthoud, No. 1324, may be consulted as to the curvature required for the anchor pallets, to produce the isochronous vibrations of the pendulum.

This dead-beat escapement of Graham's, when executed with the necessary care and precision, is still the most perfect which can be used for the purpose; and especially if made with ruby pallets, as is sometimes the case.

The action of this escapement is thus:—The pallet a we may suppose has escaped, and the other pallet b receives a tooth of the swing-wheel upon its cylindrical portion; the vibration is completed, and the pallet enters the tooth completely without touching it; the returning vibration is made, and the wheel remains stationary until the inclined surface of the pallet presents itself to the point of the tooth—the tooth then acts upon it, the pallet is driven off, and at its escape the tooth c strikes the cylindrical portion of the pallet a, and is retained until the inclined surface presents itself; the wheel is then in action, follows the inclined surface of the pallet, and passing it, gives motion to the pendulum.

U 9.

The dead-beat cylinder escapement for watches, invented by Graham.

F is the scape-wheel of twelve teeth, upon each of which is fixed a small wedge or inclined plane i; on the verge or axis of the balance, there is fixed a portion of a hollow cylinder of steel or other hard material, as is shewn at B in the figure; the interior diameter of this hollow cylindrical portion is equal to the length of one tooth of the wheel, and is at liberty to revolve about the tooth nearly one turn. It will be seen by this description, that when the balance ad-

vances from a, towards b and c, the wheel F is in a quiescent state; and when the point a arrives at the extremity of the inclined plane i, the action of the wheel will be thereby transmitted to the balance, and the inclined plane rests upon the interior C of the cylinder; the wheel has another interval of repose, the balance returns in the opposite direction, again receives the action of the same inclined plane at its exit at C, and the following tooth applies itself to its exterior curve in the same manner as the preceding one, and so on of the rest. See the description of this escapement, in the Traité d'horlogerie de Lepaute, printed in 1755, page 171; in l'Essai sur l'horlogerie par Ferdinand Berthoud, Paris, 1786, vol. i, page 131; and in the Traité des echappemens par Jodin, Paris, 1754, page 132.

A 9′.

Dead-beat pin escapement, by M. Amant, clockmaker of Paris.

It is composed of a plane wheel, on which is arranged a circular line of pins. The pin I quits the pallet A, and the pallet B receives the impulse of the escapement; the vibration continuing, the pallet B falls, and the wheel rests, the seconds hand of this escapement has therefore no recoil. The vibration is repeated, the pin acts upon the inclined plane, restores the movement, and so on.

We here see that in dead-beat escapements as soon as a tooth of the scape-wheel has effected its impulsion of the balance, the same tooth rests on a portion of a cylinder which is carried by the balance, so that this tooth acts upon the cylindric portion of that axis during the whole time occupied by the balance in completing its vibration. Now, as this cylindrical portion of the axis is of course contiguous to it, it necessarily follows that while the balance completes its vibration, and the action of the scape-wheel is thus suspended by the cylindric portion of that axis, the scape-wheel itself will be perfectly quiescent; that is to say—it will never advance nor recede, whence the appellation of this escapement is that of repose, or dead-beat escapement; but notwithstanding the apparent advantages of this escapement, its principle of construction renders it naturally liable to much detrimental influence from oil, friction, and other consequent irregularities, however perfect may be its mechanical execution. M. Berthoud states—that these difficulties or defects in the common dead-beat es-

capements, induced him to seek the practical means of remedying them: for this purpose he arranges the escapement in such a manner that when the wheel has produced its impulsion, the balance may complete its vibration freely, and that during that time, the action of the wheel shall not be interrupted by the balance itself, as in the common dead-beat escapement, but by a detent which is disengaged by an instantaneous movement, so that the balance may not thereby encounter any other resistance or friction than what arises from the disengagement of the detent; and further, that the impulsion of the wheel shall be transferred to the balance with the least possible quantity of friction, and under circumstances which shall obviate the necessity of applying oil to the works. Such were the original ideas of M. Berthoud of the requisite construction for an escapement, which he denominated a free vibration or detached escapement.

In this escapement the balance makes two vibrations while but one tooth of the wheel escapes at a time, that is to say—that the balance shall vibrate on itself, and that the wheel in its escape at the return of the second vibration, shall restore to the regulator in one vibration, the loss of maintaining power which it has sustained in two. Thus, during the whole time of one vibration, and the greater portion of the second, the action of the wheel will remain suspended by the detent, allowing the balance to vibrate freely.

The invention of the free or detached escapement seems to belong equally to different artists, who without any inter-communication among themselves, had, as it should seem, nearly the same ideas of the subject. The persons who thus seem equally entitled to claim priority of invention are Le Roy, Mudge, and Ferdinand Berthoud. It appears however, that many years antecedent to this, J. Dutertre had organized a similar contrivance, but which was not published, and we are consequently unacquainted with the particulars of its construction.

B 9′.

Free escapement, as invented by Arnold.

C is the scape-wheel of this escapement; D a circular piece set on the axis of the balance; t a small projecting point from the axis; n m a spring having

its centre of motion in n; the action of this spring is to press constantly towards the wheel C, and its progress in that course is checked by the projecting piece q; a point p also projects upwards from its extremity m. The spring n m carries a second spring r s of extremely delicate form and action, and which has its point of support in r.

This understood, we will imagine the balance to vibrate in the direction indicated by the dart in the figure; the projecting pin t, will then fall into contact with the extremity s of the finer spring r s, which opposing little resistance, will allow it to pass; but at the returning vibration in the contrary direction, the spring r s will meet the obstacle p, and instead of bending in the point of support r, it will cause the first spring n m to bend on the point n, and will consequently allow the escape of a tooth of the wheel C; at this moment another tooth of C will strike into the indention of the piece D, and restores the loss of power to the balance. Thus at each double vibration of the balance, the point q of the spring n m releases a tooth of the wheel C, and the balance receives a new impulsion.

C 9′.

Free Escapement, by Ferdinand Berthoud.

The description of this escapement is extracted from the inventor's work—Histoire de la mesure du temps par les horloges, vol. ii, page 35.

In the figure, A represents the escapement wheel, a b c the detent; the arm a of the detent suspends the action of the wheel, while the balance makes a free vibration; the spring d brings back this detent as soon as the pallet c has thrown off the arm b: at the same instant a tooth of the wheel A acts upon the cylinder h which is carried by the regulator, and transmits the maintaining power to the balance; the balance having completed another vibration—returns, and in its retrograde motion the pallet c meets the end b of the detent; but this recedes, flying off from the arm b and towards the centre of the more distant circle from b, and the spring l brings it back to its action when the balance has completed its vibration; so that at its return, the pallet c is again presented to the arm of the detent to disengage the wheel and repeat the impulsion of the balance.

Haley's free Remontoire Escapement.

In the year 1796 Mr. Charles Haley, an English watchmaker, obtained a patent for a free remontoire escapement: a description of which is inserted in the Repertory of Arts and Manufactures, No. xxxiii, page 145. Vol. VI.; and in the Annales des Arts et Manufactures, Vol. VIII. page 38; and M. Berthoud has extracted an account of it in the second volume of his work—" Histoire de la mesure du temps par les horloges."

A description of the escapement of Delafons may also be seen in—" Les Annales des Arts et Manufactures, Vol. ix, page 69."

D 9′.

Description of Breguet's Remontoire Escapement for Watches.

This account is extracted from Berthoud's " Histoire de la mesure du temps par les horloges, Vol. ii, page 55."

A A is a plate of metal upon which is fixed the entire movement of the escapement.

In order clearly to describe the mechanism of this escapement, it will be more satisfactory to the reader to consider it under three distinct portions or divisions, the respective action of which will be stated separately, and their relation to each other afterwards explained.

Part 1. This portion of the arrangement is composed 1st of the wheels B B′ and D which are fixed to each other. The wheel B B is placed in action with the moving power by a train of wheels, which produce its rotation in the direction B C B′.

2nd—Of a pinion g which drives the wheel B B′; its teeth are equal in number to so many of those of the wheel B B′ which are contained in the space between two following teeth of the wheel D D′. This pinion will therefore at each of its revolutions be opposite to a tooth of the wheel DD′. On the axis of the pinion is a fly i g h; the branch g i of which, is shorter than the other g h, at the extremity of which is a small piece of steel.

3rd.—It contains a check spring r r F, fixed at the end r r and placed at right angles to the direction of the fly; at about two thirds of its length from its fixed end, there projects a piece V which carries a ruby or other precious stone, or a piece of tempered steel. In that state of the mechanism which is represented in the figure, the ruby presses against the extremity h of the fly; and so performs the office of a stop, which prevents the fly from moving in the direction in which the pinion g would carry it by the action of the wheel B B′; it thus suspends the motion of the wheel B B′, and consequently the action of the moving power. But if from any cause the spring r r F is inflected on the side of the pinion g, at the moment that the stud V, comes opposite to the notch near the extremity h, the fly escapes, and performs one revolution; and if at the completion of that revolution the spring r r F has taken its first position, it will be stopped by the stud V and will pass no further.

Part II.—The second portion of the arrangement is composed——

1st. Of an impelling spring G, curved at its extremity. This spring, as will be more fully explained hereafter, serves to restore the maintaining power to the regulator at each oscillation; it carries a projecting piece or catch m, within which is a small notch, having a ruby projecting from its interior surface. When the impelling spring is inflected by the action of the wheel D D′ which communicates to it the action of the first mover, it is checked by this catch and its stud together with a piece we shall presently describe.

2nd.—Of a check spring a H, fixed at its extremity a, and upon which is fastened a very delicate spring N. The spring H carries a ruby p, which enters into the notch of the catch m, and fixes the spring at its inflection. Another jewelled stud placed at its extremity s holds the spring N, so that the end of the spring, pressed from right to left offers but little resistance; and pressed from left to right, it throws all its effort upon the stud s, and inflecting the spring H disengages the jewel p from the cavity of the catch m.

3rd.—The pieces K and b are carried by the upper extremity of the axis of the balance, and are so placed as to form an angle of 90 degrees between them. When the balance vibrates from right to left, or in the direction b K, the piece K inflects the spring, and passes beyond it; and the piece b being situated

above the plane of the wheel B B′ and below that of the spring H, the vibration from right to left is performed freely, and without any other obstacle than the flexion of the spring N. But when the balance afterwards vibrates in the contrary direction from left to right, the piece K presses the spring N against the stud s, the spring H is inflected, the stud p is disengaged from the catch m, and the spring G, left to its own action, operates as we shall presently describe.

On preserving and communicating the sustaining Power.

The action of the arrangements for preserving and communicating the sustaining power, will be clearly understood from the preceding description. At the instant the stud p of the spring H is disengaged from the catch m of the spring G, and G is released, the straight side of the piece b is at right angles to the direction of the extremity q of the spring, which strikes it, and imparts to the balance the power necessary to enable it to complete its vibration: immediately after this first percussion, the same extremity q strikes the end F of the spring F r r, inflects it and drives the stud V opposite to a notch in the fly i h, which is thus released; and the moving power which acts on the wheel B B′ and thus on the pinion will cause it to perform one revolution, at the completion of which, the spring F r r being again in its first position, it is checked by the stud V; but during this revolution, a tooth of the wheel D D′ has pressed against the projection n (which is shewn near the end q of the spring G) and has forced it back; and this action continuing according to the relation of the wheels B and D, until the stud p of the spring H is again engaged in the catch m; every part of the machine will then be in the situation represented in the figure, and the action be repeated as before.

E 9′.

This piece of mechanism is a remontoire escapement for clocks, and is invented by M. Breguet.

A is the last mover, and moves from right to left in the direction of the dart shown in the figure.

B, a wheel of six curved teeth, set on the axis of the wheel A; but at its opposite extremity.

C, a pinion acting with the wheel A, and performing six revolutions for one revolution of the wheel A.

D, A fly-wheel set on the arbor of the pinion and fixed there by its friction only; by the operation of a small spring, it is allowed to continue its motion, when the pinion is suddenly checked.

E, a small vane, or cross-piece of steel fixed on the arbor of the pinion C, and resting against the stop or check-piece F.

F, the above-mentioned check-piece, turning on the pivot V.

G, an arbor which carries three pieces of considerable importance in the arrangement:—1. The piece c, which has on one side the curved tail-piece or tooth d, and on the opposite side two ratchet teeth e f: the first of these operates to stop the motion of the arbor by means of the check-piece H, and the second, to impel the pendulum when the arbor is entirely free;—2. A pin, or small roller g, fixed in the piece c for the purpose of raising the check-piece F;—3. A small weight h, whose distance from the axis may be varied by means of a screw adjustment, in order to regulate the impelling force which acts on the pendulum, according to the arc of oscillation required to be described.

H, a check-piece which turns freely on its centre, which is fixed to the case of the wheel-work.

I I, the bob of the pendulum, suspended to the upper extremity.

L L, a plate of copper fixed to the bob of the pendulum.

M, a small and very light lever, which at one end turns on the pivot i, and at the other presses on the pin l; the extremity furthest from the pivot carries a projecting edge-piece m, which disengages the piece H, and the arbor G.

N, an edge-piece, on which the pendulum receives its impulsion. Its projection or elevation above the plane of the plate L L should be such as will allow it to pass freely behind the piece H, and having a portion of its thickness to engage with the piece C; its lower part should glance upon the tooth f at its movement, but without any actual contact.

The moving power turns the wheel A, the cross-piece E will be stopped by

the piece F: if we suppose the bob of the pendulum to oscillate from right to left, the projecting piece m of the lever M will be in contact with the check-piece H, and will disengage the tooth e, while the piece N is presented to the impelling tooth f. The arbor G is then completely free, and the action of the weight h, as well as the weight of the tooth d, gives it a tendency to turn from right to left; and its motion being quicker than that of the pendulum, it arrives at the piece N, and impels it, the tooth f rising in its progress. The arbor G continuing its motion, the pin g comes in contact with the tail of the check F, and leaves the fly D free: the tooth d being at the same time opposite to the tooth f. Therefore, while the fly performs one revolution, the tooth p acting upon the tooth d brings the arbor G to its first position; the piece f presents itself to check the fly, and the piece H acts upon the notch e to check the arbor G. The pendulum in its motion from left to right experiences no opposition but from the head of the piece H to which the edge m applies; but the termination of these pieces being similarly sloped or inclined, the lever M raises itself, and afterwards falls to its first position.

This method of preserving the sustaining power of a pendulum in its oscillations, we consider to be the most perfect of any at present known.

F 9′. Plate 11.

In our article I 7′ we have observed that in weaving machinery, the shuttle frame is required to traverse the arc a b (F 9′) with an alternate circular motion, the axis of rotation being in C; that its velocity should not be equable, but decreasing as it approaches the extremity a of the arc a b nearest to the large roller, and accelerated as it approaches the other extremity; and that this alternate circular motion subjected to these conditions, is communicated to the shuttle frame by the direct and equable circular motion of an axle d, which is driven by any moving power.

This problem may be resolved with all desirable precision and facility, by the methods already explained; the following method by approximation has been used in England, and we have also seen its application in Paris, in the manufactory of M. Cala, an eminent constructor of spinning machinery.

Let d e represent the crank arm of the axis of rotation d, its length equal to half the chord of the arc a b; e f g a metal rod suspended in the point f to a second rod f h, which turns upon the point h. While the point e of the crank proceeds from e to e, from l to m, and from m to n, the point f of the rod h f passes from i to f, from f to s, and from s to k; and consequently the distance k i will be equal to the distance n l. The shuttle frame being required to traverse the arc a b in the same interval, the distance a i is divided into two parts i r and r a, the portion f g of the rod e f g is taken equal to r i, and a third rod g p equal in length to a r, is placed as in the figure, so that its extremities may turn freely on the points g and p of the rod e f g and the line c p of the shuttle frame; and the shuttle frame will traverse the arc a b with a velocity the variations of which will depend on the relative proportions of f g and g p; these distances will be easily arranged by a few trials.

G 9′.

Let A B represent a horizontal shaft, which receives an alternate circular motion from the moving power, n and m two ratchet wheels fixed upon the shaft so that their teeth are reversed with respect to each other; C, D and E three toothed bevel wheels, of which C and D are of equal diameter; they are held on the shaft A B by friction only; they carry the two click pieces p and q, and they work with the third wheel E, the axis of which is properly supported. The shaft A B, by its alternate circular motion, acts on the wheels C and D alternately, and soon acquire a direct circular motion; and, as this must take place in opposite directions, the wheel E will turn constantly in the same direction; and thus, the alternate circular motion of an axis or wheel, may be converted into the direct circular motion of another wheel, the direction of the second axis being at right angles to that of the first, or the plane of the second wheel being at right angles to that of the first.

H 9′.

The conversion of a direct circular motion, into an alternate circular motion, by a method sufficiently simple for practical purposes, and which will allow the

alternations to be regulated at pleasure, is a problem of universal interest with mechanics and artists of every description.

In our articles L 7′, (Plate 4), and M 7′, (Plate 5), we have given two examples of the conversion of direct circular motion into alternate rectilinear motion, by the action of a counterpoising weight, which acts alternately on the opposite sides of a vertical line passing through the axis of rotation of the arm; the alternate changes of position, taken by the weight alternates the action of an arrangement of wheel-work, which converts the rotatory motion of a spindle into an alternate motion, as in the case of the axis E F in the figure L 7′, and the two cylinders F and G in the figure M 7′; the alternate circular motion so produced is afterwards converted into alternate rectilinear motion. In these two examples we see the methods by which the change of position of the counterpoise is effected; and which are calculated for the particular purposes of these machines; but in general whenever a counterpoising weight is adopted for the conversion of direct circular motion into alternate circular, the periods of the alternation may be regulated either by some simple combination of wheel-work, or by the arrangements D 3 Plate 1, and S 8 Plate 11, which will be found of universal application.

Let MN, figure H 9′, Plate 11, represent an axis corresponding with E F in the figure L7′, Plate 4, or to one of the cylinders F or G in the figure M 7′, Plate 5; P, the counterpoising weight; n o, the axis of rotation of the vertical arm on which the counterpoise is supported; q o an arm placed at right angles to the vertical arm and the axis n o; e s r, the axis of the machine S 8 Plate 11, placed as in the figure; it will now be perfectly easy, as has been already explained, to cause the arm r s to perform only one revolution about the axis D E, while the axis M N shall make *n* revolutions at pleasure. We will now suppose that the axis r s be raised from the lower towards the upper part of the figure, and on its arriving there, the counterpoising weight P will be situated in the vertical line which passes through n o; it will now fall towards the point p′; the rotation of the axis M N will be changed; the axis s r will also return in the opposite direction, will meet the arm o q at the upper part of the figure, will

return it from the upper to the lower part, and cause the weight P to move toward p″; and so on.

I 9′.

In this figure we have a plan, and an elevation of the subject:—the figure on the right being the elevation, that on the left, the plan. The same parts of the machine has in each figure the same letters of reference respectively.

The mechanism shewn at D 3, Plate 1, may be employed here for the same purposes, as follows:—

That arrangement may be placed as in the present figure, the axis A B is terminated by a square arm g h which is fitted by its friction into an aperture cut in the centre of the pulley G; this pulley is supported by a collar, or in any sufficiently substantial way, which will not impede the rotatory motion; the moveable nut M′ carries a forked piece or double-armed lever i k l m; an endless rope passes round the axis M N and the pulley G, by means of the fixed pulley H.

The circular motion of the axis M N is communicated to the pulley G, and consequently to the axis A B; and this axis in its rotation is at liberty to rise or fall freely; if we suppose the nut M′ to rise, the lower branch m l of the forked piece i k l m will come into contact with the lever o q of the counterpoise P, and cause the weight to fall towards the right hand; (see the plan) the arbor M N at the same time will move in the opposite direction; the nut M will descend, and the upper branch i k of the forked piece comes into contact with the lever o q, and by its action carry the weight P over and allow it to fall on the other side, in the period proposed; and so on. An arrangement of pulleys of different diameters may be substituted for the pulley G, as is done in the toothed wheel B of the mechanism S 8, Plate 11; the periods of intermission of the alternate circular motion, may by this means be varied at pleasure.

The mechanism shewn in our subject P 3, Plate 10, may be also used as an auxiliary method of resolving this problem.

K 9′.

This figure comprehends a plan and two elevations for the illustration of the

subject, in which as usual, the same letters of reference are respectively affixed to the same parts.

The mechanism shewn in our figure S 8, Plate 11, also applies directly to the general solution of this problem, without the necessity of a counterpoising weight; thus, let A B and C D represent two axes, each of which carries a pulley, a of one of them, a′ of the other; and also a toothed wheel on each, b and b′. An endless rope or band presses crosswise over the pullies a and a′, and produces their simultaneous circular motion, in opposite directions. Let E F represent another axis carrying a toothed wheel c, this axis is at liberty to alter its distance from the axes A B and C D, or to move between them approaching one of them, while it recedes from the other, its pivots being let into the oblong aperture d d′; it thus operates to carry the wheel c into working contact with the wheels b and b′ alternately, and so to convert the direct circular motion of the axes A B and C D into alternate circular motion.

An attentive inspection of the several figures of this subject, with reference to the description already given in our article S 8 will give a complete idea of this mechanism. In the two upper figures of K 9′, or the plans, the curves e f g h, e′ f′ g′ h′ will be observed; each of which is composed of two parts, the first portion of each is circular and they are respectively marked e f g, and e′ f′ g′; these portions support the axis E F alternately in its bearings towards C D and A B, the other portions g h and g′ h′ operate to communicate the shifting movement to the axis E F.

SECTION X.

To convert direct circular motion, of uniform velocity, or which varies by a given law, into that of a curve of given species, direct and continuous, of velocity similar to that of the moving power, either equable, or variable by a given law, and in the same or in different planes of direction.

A 10. Plate 8.

First general Solution of the Problem.

Let F represent the given curve; and let it be required to trace or describe it

mechanically by a pencil or other instrument upon the surface P Q by means of the direct circular motion of the wheel D. For this purpose three wheels A, B, C must be taken of suitable diameter, and arranged as shewn in the figure, and which shall receive their motion through the operation, and by their connection with the wheel D; m n, p q are two rulers or bars, which are at liberty to traverse to and fro in the clips or directing grooves a, b, c, d. They are terminated in m and q by two rulers or bars r s, t u, each having a straight groove or channel cut through it. The pencil or instrument with which the curve is to be traced is to be fixed at the point of intersection of these two grooves. A certain number of points are assumed at pleasure upon the given curve, and the number of them for the reasons explained in the article A 7, should be encreased at those points of the curve at which the most abrupt changes of direction take place. The proper curves thus obtained must be traced, and placed on the surfaces A and C in relief, and so arranged that the extremities n and p of the tracing points shall be pressed into constant contact with them by means of springs or other suitable contrivances; and the points of intersection of the grooves or the positions of the pencil, will then traverse the previously determined points.

From this mechanism might easily be devised a mechanical method of explaining the laws of the resolution of forces, and the motion of projectiles in a resisting medium or otherwise; if such methods might be considered of sufficient importance to warrant our thus encreasing the number of our scientific apparatus and instruments, which it must be confessed seem already to be more numerous than the legitimate purposes of science properly require.

B 10.

The general solution which we have given of this problem in the preceding article, is the only solution which accords with the plan of our analytical table, in which the principal object is to shew the transformation of one movement to another. But in the practical arts, it is essential not merely that the desired result be produced, but that it should unite simplicity of arrangement, with a facility of construction, and which shall be effective and suited to the habits and

comprehension of workmen. For the due performance of these conditions, the movements should be judiciously arranged with respect to the different parts of the machine, and as the distribution of parts will be arbitrary, the same end may therefore be produced in various different ways. It is the business of an accomplished mechanist to calculate all the practicable combinations which may be made with the component parts of a given machine, and the required number of movements, and to adopt the most simple and effective.

The object of the problem we are now considering, is not so much to produce the curvilinear motion of a given point, or tool of any description, as to describe that curve on a given plane surface. To this end, the surface P Q is attached to the extremity of the arm p q; this surface, which was previously fixed, will thereby receive an alternate rectilinear motion; having fixed the pencil or cutting tool to the end m of the other arm m n, corresponding curves will be traced on the surfaces A and C, and a machine will thus be obtained which we consider to possess much novelty and usefulness.

Second general Solution of the Problem.

The principal points of a given curve may also be governed by angular coordinates. These curves are of two descriptions:—1. Continuous or returning curves, in the interior of which a point may be determined—such as that all right lines passing through it, shall pass through but two points in that curve. 2. Similar curves in the interior of which no point can be assumed which possesses that property.

The curves of the first-mentioned description may be easily described by a direct circular motion, thus: Let A B D, (figure α, plate 10.) represent the given curve, and let any point C be taken within it for the centre of rotation of the circular movement of the bar P Q, which revolves in the same direction, while the bar T O slides upon PQ. During the motion of the point O over the given curve, the end T traces another a b d, and reciprocally, the assumed length of the bar O T being arbitrary, the bar O T′, might have been taken instead of it, in which case the curve a′ b′ d′ would have been produced, answering the proposed conditions of the problem.

The curves of the second description involve some difficulty. Let A, B, D, (figure β, plate 10.) represent the given curve: there does not appear on the

first consideration any general solution of this problem, in whatever position the point C may be assumed; for the circular movement of the bar P Q being direct, while the bar OT follows its direction the solution of this problem thus becomes impossible; a little further consideration however will indicate the method of proceeding.

Suppose that the line O T (figure 8, plate 10.) instead of being placed in the direction P Q, shall make a constant angle with it as C O T; if during the passage of the arm P Q to the position P′ Q′, the point O approaches the centre and arrives at O′, the point T will pass to T′, having experienced a retrograde movement relatively to the movement of P Q. This will sufficiently point out the practicability of a general solution of the problem.

A detail of all the operations connected with this subject, would lead us into considerations essentially distinct from the general object of our work. We shall therefore pass on to our usual descriptive mode of explaining the practical applications of the problem.

Having shewn the methods of tracing curves formed by a circular, and an alternate rectilinear motion, we will now suppose the surface on which the curve is to be traced, to have a circular movement while the line T O has an alternate rectilinear motion, so that the whole line, or only the point O of it shall be constantly found in the direction of a radius of the circle described by a given point of the revolving surface.

In this point of view, we find this problem give rise to a practical art of great elegance and utility, viz.—The branch of ornamental turning, which is termed —rose engine turning. Much practical information in this art may be obtained from " le Manuel des tourneur de Bergeron," and the French " Encyclopédie."

In the Memoirs of the French Academy of Sciences for the year 1734 we find two Memoirs on this subject by M. de la Condamine; the first given at page 216, is entitled " Recherches sur le tour; Description et usage d'une Machine qui imite le Mouvement du tour*.

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* M. de la Condamine in his second Memoir, gives the solution of some problems analogous to those general ones whose solution we have here pointed out; he however considers them in a different point of view.

We have introduced the simple method shewn at C 10 of our plate 8, as an effective substitute for M de la Condamine's machine. It is composed of an auxiliary wheel A, which drives two other wheels B and C, which in the latter are placed on the same axis. The rosette D is affixed to the first wheel B; the pin m n, which is attached to the sliding bar P Q, presses upon its edge by means of a spring a b acting on the end p of the bar. At the point q of the moveable arm p q is set a point or pencil which may be placed at pleasure in any part of a circle of paper placed on the surface C.

The practical use of this machine is, as M. de la Condamine observes, to determine the variety of figures which may be described by the tool, from the same rosette, a matter extremely easy to accomplish. We shall refer to his memoir for a detailed account of the various forms to be obtained by changing the rosette, or varying the position of the tool or pencil.

In actual practice, those rosettes will be found most commodious, the lines of which form the most obtuse angles; the motion of the pin m n is thus rendered more uniformly steady.

M. de la Condamine observes, that the second practical use of the machine, is to determine the proper species of rosette suitable to any given design.

He says, " Having properly determined the place of the tracing point, " and secured it in the required position, it only remains to set it by hand " to the design for which the rosette is required; and the other extremity of the " bar which in the common use of the machine, is pressed upon the edge of the " rosette, will trace the rosette required. For the present purpose therefore, a " plane surface of paper or pasteboard is substituted on the wheel B for the " model of the rosette before placed there, and the end m of the point m n, " which in the former case applied itself on the outline of the rosette, will now " carry a pencil which will describe the outline of the figure required."

D 10.

The second memoir of M. de la Condamine, page 303, of the Memoirs of the Academy, is entitled—" Recherches sur le tour, second memoire. Examen de

la nature des courbes qui peuvent se tracer par les mouvemens du tour." He gives the solutions of the two following problems.

Problem 1.—The outline of any rosette being given, with the respective positions of the centres of the tracing point, and the cutting tool, in the same plane, to determine on that plane every point of the corresponding design.

2.—Any design or outline being given, with the position of the centres of the tracing point or of the cutting tool, to determine on the same plane, the outline of a corresponding rosette.

The solution of these problems is so simple, that we do not consider it necessary to enter into any detailed explanation of them. For further particulars on the subject, the memoir itself may be consulted.

M. de la Condamine afterwards gives the description of the instrument shewn at D 10, which, he observes, affords a ready and correct mode of determining at once, and of describing by a direct motion, rosettes for the production of every possible outline of a given design; or reciprocally, to trace every possible design to be obtained from any given rosette, and this without the necessity of wrought models, as in the machine described in the first memoir.—A B C D is a bar or rule of three inches in length, having a longitudinal groove; the portion A B is perforated with several screw apertures, in any of which the point B may be screwed so as to vary its distance from the end A as may be required; the bar A B C D is held or supported by the clips E G of a second bar, which is also perforated with a longitudinal groove; the first bar has a sliding motion through the second, which carries a small hollow spring cylinder or barrel L, the action of which tends constantly to draw the longer bar in the direction D A, being attached to it by the band D; the lower bar also carries a second point N, which consequently tends continually towards the centre P, by the action of the spring; the centre is determined by a third point P, which passes through both bars, and is fixed to the lower bar E G, at any required point, by the nut z. The instrument is applied in the following manner:

Let the outline of the profile head at T, be the figure for which a suitable rosette is required; having first cut this profile accurately in thick pasteboard, it is glued or otherwise firmly attached to a second surface of the same material

RS, a point T is assumed at pleasure for a centre, within the outline of the subject; the two cards are then perforated in the point T, and they are together fastened down on a plane surface, passing the point P through the perforation; after which the point N is placed in contact with any part of the outline; the whole instrument is then turned by hand on its centre of rotation P, keeping the point N in constant contact with the outline of the subject, or in some cases, it may be preferable to turn the pasteboard on its centre of rotation with one hand, while the instrument is held firm with the other, attention being paid at the same time to the accurate and uniform contact of the point N with the contour of the subject.

In both these cases, the point B bearing on the surface of the large pasteboard RS will describe the line VX, which is the contour of the required rosette; the point N drawn continually towards the centre P by the action of the spring L, and its progress in that direction restrained by the relief or thickness of the subject, will follow its outline with great facility and correctness so long as it does not lie in the direction of a right line drawn from the centre, which must be attended to, and avoided as much as possible in determining the point within the figure for the centre of rotation of the instrument. If in any instance this cannot be entirely avoided, as in the present subject where the lines which depict the lower portions of the nose and the chin lie in the objected direction, and that therefore the tracing point N cannot have its requisite bearing on the edge of the subject, but slides upon it, the action must be carefully assisted by the hand; this inconvenience may also be avoided in a great degree by turning the surface in an opposite direction *. Thus, in this instance the tracing point will not move up from the nostril of the figure towards the extremity of the nose, without the assistance of the hand, but will by the last-mentioned method slide

* The author's directions in these respects should however be followed with considerable caution: it appears to us, that under the circumstances stated, the requisite assistance cannot be supplied either by the manual adjustment, or the reversed rotation he recommends, but that the required correction must be sought by placing the point B out of the direction A D in a suitable manner, so as to avoid the obstacles in question; which may generally be accomplished with practice and attention.

easily over that portion of the outline, and will be drawn back again by the action of the spring. It must be observed, that in changing the centre P, or separating the two points B and N in a greater or less degree, different outlines will be produced, of which those will be chosen for the model which have the most easy and flowing curvature, and which are the most practicable in the subsequent operation of turning. It will be proper to verify this process of production of the curve, before it is cut, by a process of reversal, that is to say, by carrying a tracing point round the curve produced, and observing if the point N correctly retraces the original outline of the subject.

In this instrument we have supposed the tracer, the centre, and the cutting tool to be situated in a right line, that arrangement being at once the most simple and the most commodious in practice. The effect of oblique positions may be easily obtained, by affixing a small arm moveable on a stud or centre pin at the extremity A of the bar A D, to set the point B which describes the curve of the rosette out of the alignment with the centre of the point which traces the subject, and to set it at any required angle with that alignment.

In a descriptive work entitled " Traité des Instrumens de Mathématiques et Méchaniques," by Jaques de Besson, printed at Lyons in 1579 in folio, page 172, we find accounts of several constructions of compasses for describing rectilinear, curvilinear, elliptical, and spiral figures. The construction of all these instruments is founded on the principle of setting a rosette on one of the legs of a pair of plain compasses, which remains fixed, while the other is at liberty to make its rotation with the tracing point: all which methods may be considered as in fact so many varieties of the simple turning engine. One of these may be particularly remarked for its simplicity of construction, in which, instead of an elliptical rosette, a moveable circle is so adapted that its inclination may be altered at pleasure, and it is also capable of describing any required ellipsis with the same rosette.

In Vol. VII, No. 455 of " Machines approuvées par l'Academie Royale des Sciences," we find the description of a pair of compasses for describing spiral lines, by M. de Thiliéres. It is observed at the close of the memoir, that the second addition of the inventor was detailed in a memoir transmitted to the Academy in August 1745 for a note in the history of 1742.

The little instrument for describing ellipses shewn at Figure 8, Plate 12, is remarkable for its extreme simplicity.

A circular plate either of metal, wood, or any material of sufficient firmness of texture, and of any diameter, has two grooves n n and m m, formed on its surface at right angles to each other, the grooves are of dove-tail construction, and two sliding pieces B and C of corresponding form are placed in them one in each, and are at liberty to move back and forward in them, with a small degree of friction; from the upper side of each of these pieces there projects a small point or cylinder, these points fit into cylindrical holes drilled in the under side of the ruler or bar B D, one of them at the extremity B, the other at some distance from the first, along the bar. A pencil or point of any sort, is then held firmly to any part of the bar, and the bar being turned about on the two centres of rotation, which are thus both in motion at once, the pencil will describe an ellipse, the excentricity of which may be varied at pleasure.

Descriptions of two ellipsographs of much merit are given in the Bulletin de la Societé d'Encouragement, Vol. xvi, for 1817, page 13; and a description of an ellipsograph by Mr. William Cubitt, will be found in the Transactions of the Society of Arts, &c. of London, Vol. xxxiv. for 1817, page 131.

E 10. Plate 8.

Let A, N, B, C, represent a train of toothed wheels, whose diameters are respectively as the numbers 2, 1, 2 and 4; let a′ b′ represent a bar, whose extremity a′ may be successively fixed to the points 0, 1 and 2 of the wheel A, and adjusted also to contact with the points a c of N, 0 and 1 of B. These points being so placed that they may be in a right line in one position of the train, every point of the bar a′ b′ will move in one curve themselves, and will describe another on the revolving surface below it.

These curves assume forms which merit an attentive consideration, and are of much importance in the arts. It will be evident that they may be produced in an infinite variety, by the various combinations which may be made from the original places of the points 0, 1 and 2 of the wheel A, a, c of the wheel N, 0 and 1 of the wheel B, and other points taken out of the direction of the bar a′ b′.

The ratio of the diameters of the wheels, and the number of them will also give rise to new varieties in the character of the curves. This machine will be considered as a contrivance which may be usefully adopted under particular circumstances, but the curves it produces may also be described by the preceding movements A 10, B 10, C 10, D 10.

F 10.

Problem.—To describe a continuous spiral on the convex surface of a given cylinder.

It will be recollected that this is in fact the process of describing the helix of a screw of a given diameter.

Let A B represent a fixed axis; to which is firmly attached the cylinder C, on the convex surface of which it is required to describe the spiral: and the toothed wheel D. M L K N is a frame having a rotatory motion on the fixed axis A B; between the arms L M, K N, is fixed the axis F G, which has a movement of rotation on itself, and carries a toothed wheel E, which drives the wheel D; and also a male screw H I with its nut P: the nut carries an arm O P at right angles to the axis of the screw; the extremity O of this arm moves in a groove which extends longitudinally through the extent of the bar L K of the frame, and at the other extremity carries a pencil, or cutting tool.

Method of using the Machine.

Let the radius of the wheel E be called α, that of the wheel D be called β, and the thread of the screw cut on the cylinder H I be called δ. If now the frame M L K N be made to describe one revolution about the axis A B, the wheel E and consequently the cylinder H I will in the same time describe a portion of one revolution about the axis F G equal to $\frac{\beta}{\alpha}$, and the pencil, or cutting tool, will in the same time traverse a distance equal to $\frac{\delta\beta}{\alpha}$, which will represent the quantity measuring the thread of the required screw, or the quantity of one revolution of the helix to be described on the cylinder C. The value of this quantity will of course be variable at pleasure, by suitable alterations in the relation of α to β, or that of δ, by the introduction of different guiding screws.

It has already been noticed (in our article C 3) that, when the nut is fixed, and the screw is made to revolve, the movement will be compounded of a rotatory motion and one of conversion. This compound movement is precisely that which is required for tracing this helical line; and it consequently affords the solution of the stated problem. The movement has been frequently applied in the construction of pendulum clocks and clepsydræ, and of hygrometers. In these several machines or instruments the helical line is described on the convex surface of a cylindrical column, and so becomes the scale on which the progress of its action is indicated.

An hygrometer on this construction is described in Leupold's "Théatre universel de la Statique," 1726, plate 16.

In this instrument of Leupold's the hygrometric action is supposed to be immediately directed against a small rack a b, (see our plate 12, figure 9) thus producing in it an alternate rectilinear motion of small extent; the axle A carries a toothed wheel B, and a pinion C; it is so arranged that the pinion is driven by the action of the rack, whose alternate rectilinear motion is thus converted into alternate circular; the sensible effect of this motion will be encreased as the diameter of the wheel B exceeds that of the pinion C. The axis n m carries the horizontal circular plate p q, which indicates by its index s the hygrometric gradations of the instrument, or the hour, on a properly divided helical line which may be traced upon the convex surface of the cylindrical column. The axis n m is composed of two portions essentially distinct: one of them n r is a male screw working in the fixed nut F; the other r m is a square bar which slides with some degree of friction in a socket or aperture of the same form, in the centre of the toothed wheel t u; this wheel is driven by the wheel B; it is supported by the flanch piece x x, which rests on the cross framing D E. The alternate circular movement of the wheel B will be transmitted to the wheel t u; and the motion of the axis n m, and the index s, will consequently be a compound alternate motion, as the subject requires.

G 10. Plate 8.

This figure consists of a plan, and a side elevation in distinct arrangement, with the same letters of reference as usual.

When a spiral is required to give a traversing motion to a point, it is generally for the purpose of describing a curve on the exterior or convex surface of a cylinder. In these cases, as we have shewn in the article B 10, the arrangement is much simplified by dividing the movement, or converting it into a circular and a rectilinear motion. A rectilinear movement of conversion may be given to the cylinder on which the spiral is to be described, in the direction of its axis, while the point or tracing tool moves round it; or the cylinder may have a movement of rotation on its axis, while the tracing tool traverses in a line parallel to the axis of the cylinder. The latter method is more generally convenient, and is therefore adopted in the machinery used for cutting screws of large dimensions: An engine upon this plan has been erected at Chaillot, and another by Saleneuve.

The following description will explain the elementary construction of this useful engine. F G in the figure represents the cylinder, by whose action the rectilinear motion is produced, and communicates it to the tracing tool by means of its nut P; it has a rotatory motion on its axis, and is secured in its position by the collars H and I. E is a toothed wheel set upon the upper extremity of the guiding cylinder F G, and C is the cylinder on which the required screw is to be cut; it is mounted upon centres, and a toothed wheel D is fixed on its upper extremity; the cylinders C and F G must be set perfectly parallel to each other. A is a third or auxiliary wheel which drives the wheels D and E; the wheel A must be capable of adjustment, so as to accommodate itself to any required change of the wheel D, for the purpose of varying the relation between the radii of the wheels D and E. If the difference between these should be so considerable as that the fixed distance of the two cylinders prevents its being effected by the wheels D and E themselves, and circumstances should also render it impossible to change the guiding cylinder, the difficulty will be obviated by removing the wheel A, and substituting another wheel with a suitable pinion.

H 10.

The machine represented in this figure exhibits a method of superseding the guiding cylinder or screw of the last figure. A rack is here substituted, the rectilinear movement of which is produced by that of the cylinder on which the

required screw or spiral is to be cut. The practical result will be the same as under the last arrangement, but the machine will probably not unite all the advantages of the former. We give this example however principally to cultivate the habit of considering every practicable combination, previous to a final determination upon any.

The required rectilinear movement may also be communicated to the tracing tool by means of an inclined plane, as we have shewn in our figure H 1, plate 1. By an arrangement of this sort, the effect of every possible variety of screw may be obtained simply by varying the inclination of the guiding plane. This machinery will not be found suitable to the scale of dimensions required for cutting screws of large dimensions; but for screws of ordinary size, it may be applied with great facility, and will be found perfectly practicable.

The inclined plane in its application to this purpose may receive its movement either by a rack which works with the pinion D, figure C 10, plate 8, or by the action of a screw placed at right angles to the cylinder on which the required screw is to be cut. Ferdinand Berthoud, in his Essai sur l'horlogerie, Paris, 1786, vol. i. page 150, describes an engine for cutting fusees, in which an inclined plane is used to guide the tracing tool, and is moved by a rack and pinion.

I 10.

The machine here shewn, is a modification of the mechanism described in our article E 10. We extract the following account of it from the work of M. Prony, entitled—Nouvelle Architecture Hydraulique, vol. ii. page 141.

The author says, " We extract the following description of this instrument " from Adams's work on mathematical instruments entitled—Geometrical and " Graphical Essays, &c. London, 1791. The inventor, however, appears to be " Jean Baptiste Suardi, who has himself described it in an Italian work, entitled " Nuovo Istromento per la Descrizione de diverse Curve antiche e moderne, &c.; and he gives it the appellation of—Geometric pen.

" The Geometric pen is represented in an horizontal plan in the figure; it is " fixed upon a table or drawing board by means of the arms A, B and C; the " heads a a of two of these arms revolve on a common axis, so that they may be

" brought into the direction of the third arm at pleasure; and also for the pur-
" pose of rendering the instrument more portable.

" At the lower part of the axis D, which is fixed, and is of one piece with the
" supporting arm C, is fixed a toothed wheel i, which may be changed occasional-
" ly, but when in use, is firmly attached to the axis D and is also immoveable.
" E G is a bar or arm of metal, open, or double horizontally in the greater part
" of its length, its extremity E is held between the piece k, and the wheel i,
" but having free liberty of motion about the axis D. A sliding nut b is ar-
" ranged to slide at pleasure along the opening or groove of the arm E G, and
" can be tightened and fixed at any required point of its length. This nut carries
" a second toothed wheel h, which may be changed when required, and accord-
" ing to the situation of the nut b on the arm, may either act immediately on
" the wheel i, or may receive the movement by an intermediate wheel as is
" shewn in the figure.

" The axis of the toothed wheel h is fixed in a cylindrical stud which is attached
" to a lower clip piece c; a bar f g slides in this clip, and carries a pencil K
" at its extremity, by which the required curve is to be described. The pencil
" is adjustible at pleasure as to its distance from the axis of the wheel h, by
" means of the clip c, in which the arm f g readily moves.

" This arrangement of the instrument being clearly understood, it will be
" evident that if the arm E G be moved about the axis D, the toothed wheel h
" will perform an entire movement of conversion about that axis, and a particular
" movement of rotation about its own axis; the ratio of the angular velo-
" cities of these motions, depends on the intermediate toothed wheels, and the
" relation of the respective numbers of their teeth. The clip piece c, and the pen-
" cil K have also a movement of rotation with the wheel h about its centre, besides
" the general movement about the axis D; and the curve which will be described
" by the pencil K will be determined by the ratio of the angular velocities above-
" mentioned as well as by the relation between the radii D b and b k.

" These relative proportions may be varied at pleasure, either by applying
" different combinations of wheels, or by a different adjustment of the arms E G
" and f g in their respective clip pieces; it is therefore evident that the instrument

" is capable of producing an infinite variety of lines, all of which shall differ from " circular lines, and which nevertheless will be produced by a combination of " circular movements. A moderate acquaintance with geometry, will enable " the reader to practice himself in devising combinations for the production of " given curves.

" Adams also asserts, that the principle of this machine was applied by Bolton " and Watt to their improvements of the steam engine; and this has since been " confirmed."

K 10.

In this figure, A represents a square plate; B a cylinder fixed on its surface; its edge is grooved so as to become a sort of pulley; a b c, d e f, are two ropes or bands which pass round the cylinder B on opposite sides, the terminations of one of those bands are in the points a and d on the left hand bar of the figure; those of the other are in the points c and f on the opposite bar of the figure; the bars to which these bands are thus attached are placed parallel to each other, the points of attachment are certain pins which are set on each bar for that purpose. Now if an alternate rectilinear movement be given to the last mentioned bar, in the direction of its length, the plate A will also assume a similar and corresponding movement, but will at the same time have a rotation on the centre of the cylinder B, every point of the surface of which, except that which marks its centre, will decribe an epicycloidal curve.

We have seen this contrivance applied to machines for grinding and polishing mirrors.

L 10.

In this figure we have a front, and a side elevation of the subject, with the same corresponding letters of reference.

A B represents a fixed bar, fitted with a line of projecting pins a a, &c.; E D E is a crank movement; C D, a vertical bar whose lower extremity C occupies the space between two of the pins a a of the cross bar A B, while its upper extremity D, which terminates in a ring is attached to the end of the crank arm E D E, so that on the rotation of that axis, the bar C D has a movement compounded of an alternate rectilinear motion, and an alternate circular

motion; by this compound motion, every part of the bar C D will describe a curve which assumes the figure of a heart, of different degrees of elongation, the point or most acute portion of which is always in the direction of the fixed bar A B. N is a square plate carrying a ratchet wheel M: this plate may be fixed in any part of the bar C D, and should have a free motion of rotation upon an axis passing through the centre of the ratchet wheel M. E F G H is a claw piece terminating at E in a ring through which the end of the crank axle passes, and previously passing through a ring F which is moveable on its own axis, and is attached to the vertical bar C D, the rotation of the ring F on its axis allows the claw piece to oscillate about E, so that, at each revolution of that axis, the claw piece makes a double oscillation, and its curved termination G H is so formed that, when the extremity D of the vertical bar is at its greatest distance from the pins a a of the horizontal bar A B, the extremity H of the curve G H will have caused a small circular motion of the wheel M on its centre; by its action on the ratchet teeth, and the same effect will be repeated at each successive revolution of the axis E.

This mechanism has been adopted for the purpose of polishing mirrors, a description of the machine is given in Bailey's work, vol. ii, page 142; a model of it may also be seen in the Museum of the Repository of Arts and Trades in Paris.

M 10. Plate 11.

In our article H 10 we have explained that an inclined plane may be applied to give the required motion to the tracing tool in the manufacture of screws of ordinary dimensions; and that the inclined plane might receive its movement either by a rack, or a screw placed at right angles to the cylinder under operation; we referred to Berthoud's description of an engine for cutting fusees to shew the application of the first mentioned of these two methods. We shall now give an example of the second method for screws of small dimensions, such for instance as those usually termed wood screws used in the general operations of carpentry, &c.

A A′ is the cylinder on which the required screw is to be cut; it is supported by the two upright pieces or puppets F and G, at the extremity A is set a bevelled

toothed wheel C, the moving power used to give the cylinder the necessary rotation, is applied at the extremity A′; the axis B B′ is perpendicular to the cylinder A A′, and is supported by the two upright pieces or puppets H and I, and carries a bevelled toothed wheel D working with the wheel C; the portion g h of the axis B B′ has a screw already formed on its surface. E is a bar of metal on which a sliding piece traverses, carrying the cutting tool M; this bar is either of triangular, or quadrangular form, and is supported by the two puppets F and G. a b c d is a large and deep mortice formed in the plane on which the supporting pieces or puppets F, G, H and I are placed and supported. e f b d is a bar whose thickness is equal to the depth of the mortice a b c d; it moves within the mortice, and has a free sliding motion through its entire length. The two upright pieces or puppets K and L are placed upon the bar e f b d; the first of these terminates in a cylinder which has a circular aperture through which the axe B B′ passes, and the second of them L, terminates in the nut of the screw g h. At the extremity e f of the bar e f b d is fixed the bar e s i; the bar i k has a motion of rotation about the point i as a centre; it has a longitudinal opening or groove l m, into which passes a small cylinder attached to the sliding piece M. p and q are balls which form the upper terminations of two small cylinders, which project one of them from the bar e f b d, the other from the bar i k; and they have each free motion of rotation on their axes. The portion n o of the arm or rod n r, is cylindrical and passes through the circular aperture of the ball p; it is at liberty to turn freely, but has no sliding motion; the other portion o r, of the same rod n r, has a screw already cut on it, and it passes into its nut which is cut within the ball q.

This description being understood, it will appear that if the cylinder A A′ be made to revolve, the circular motion so produced will be transmitted to the axis B B′, the bar e f b d will be accordingly set in motion, and will carry with it the arm or bar i k. The angle of inclination of this latter may be varied at pleasure by means of the adjustment afforded by the rod n r; it will thus perform the office of an inclined plane, and will effect the guidance of the cutting tool M with the velocity which may be required.

N 10.

The arrangement L 1 might also be used in the manufacture of screws of small dimensions, thus: let M G in the figure represent a portion of an axis or spindle, comprized between the two supporting pieces or puppets r and p, and on which it is required to cut a screw, and let the portion A G of its prolongation be supposed to have a screw already cut upon it; this portion is supported by the puppet q; the screw A G passes into the nut s, and is not at liberty to turn. The bar A B is carried by the nut s, and has a free rotation on the point A; a longitudinal groove or opening n m admits the fixed cylindrical stud c.

The bar CD slides between the apertures of the three puppets r, p and q; it carries the cutting tool K, and the perpendicular arm E F. From a part of this arm, there projects the cylindrical stud a, which passes through the groove n m of the arm A B. If the axis A M be made to revolve, the nut s will advance towards G, and will carry with it the bar C D; the cutting tool K will consequently move with a velocity which may be varied at pleasure.

An application of this arrangement to a machine for cutting fusees is shewn in Thiout's Traité d'horlogerie, vol. i, page 70.

SECTION XI.

To convert direct circular motion, of uniform velocity, or which is variable according to a given law, into alternate motion in a given curve, of velocity similar to that of the original motion, either equable, or variable according to a given law, and in the same or in different planes of direction.

We are not acquainted with any direct method of solution of this problem; but if the given direct circular motion, be converted into alternate circular motion, by means of any of the methods exhibited in the examples of Section 9, these may be again converted into alternate motion in a given curve, by any of the methods shewn in Section 10, and by the arrangement A 20.

SECTION XII.

To convert direct motion in a given curve, and of velocity either equable or variable by a given law, into alternate rectilinear motion; of velocity similar to that of the original motion, either equable, or variable according to a given law, and in the same, or in different planes of direction.

THE given movement must be converted into a direct circular movement by some of the methods given in Section 10; and the direct circular movement thus obtained, changed into an alternate rectilinear movement, by Section VII.

SECTION XIII.

To convert direct motion in a given curve, and of velocity either equable, or variable by a given law, into alternate circular motion; of velocity similar to that of the original motion, either equable, or variable according to a given law, and in the same, or in different planes of direction.

THE given movement will be converted into a direct circular movement, by some of the examples of Section X.; and the movement so obtained, changed into an alternate circular movement by reference to Section IX.

SECTION XIV.

To convert direct motion in a given curve, and of velocity either equable, or variable by a given law, into motion in a given curve; of velocity similar to that of the original motion, either equable, or variable according to a given law, and in the same, or in different planes of direction.

A 14.

IF the given movement be converted into a direct circular movement by the methods shewn in Section X, the required movement in a curve, may be obtained from the direct circular movement so obtained by the same Section.

B 14. Plate 8.

The subject of this article is a pantograph, as improved by Langlois, a mathematical instrument maker. A detailed account of this instrument may be seen in the Machines approuvées par l'Academie des Sciences, Vol. vii, No. 460. It is used for the purpose of tracing similar figures of any description in any relative proportions which may be required, and with any given velocities.

In the Annales des Arts et Manufactures, vol. v, page 59, we find the description of a machine for copying drawings and writings, which the inventor terms an Autograph. It is a modification of the Pantograph.

SECTION XV.

To convert direct motion in a given curve, and of velocity either equable, or variable by a given law, into alternate motion in a given curve, of velocity similar to that of the original motion, either equable, or variable according to a given law, and in the same, or in different planes of direction.

THE given direct motion in a curve may be converted into alternate circular motion by the methods shewn in Section VIII.; and the alternate circular motion so obtained, into an alternate motion in a given curve, by the methods shewn in Section X.

SECTION XVI.

To convert alternate rectilinear motion, of velocity either equable, or variable by a given law, into alternate rectilinear motion, of velocity similar to that of the original motion, either equable, or variable according to a given law, and in the same, or in different planes of direction.

THE given alternate rectilinear motion, may be converted into circular motion by the methods given in Section VII.; and the motion so obtained, into alternate rectilinear motion, by the subjects of the same Section.

All the movements described in Section I. will also furnish a solution of this problem.

In the "Machines approuveés par l'Académie," Vol. v, No. 350, we find a machine described by M. Du Buisson, in which an inclined plane is applied to produce the required alternate rectilinear motion. The description of the machine is introduced to contribute to an history of machinery.

The small pumps which are used on board ships, and frequently for drawing liquors, in which the action is produced by an alternate motion of the operator's hand, is composed of a cylindrical tube or pipe, having a valve at its lower extremity, which is immersed in the liquid. It is sometimes indeed constructed without any valve: in this case the effect of the machine is produced by a dextrous application of the operator's thumb, at the upper extremity of the tube. These engines also belong to this division of our work.

SECTION XVII.

To convert alternate rectilinear motion, of velocity either equable, or variable by a given law, into alternate circular motion, of velocity similar to that of the original motion, either equable, or variable according to a given law, and in the same, or in different planes of direction.

A 17.

Several of the movements described in the Section III. and VII. will also be classed in this Section.

B 17. Plate 9.

In this subject, A B in the figure represents a lever, moving on the axis C as a fulcrum, which is the centre of the semicircle D E F fixed to A B. The extremities of a chain D G H K F are attached to the points D and F of the bar A B; it is adjusted by two pins so as to allow of being lengthened or shortened as occasion may require. The chain passes over two fixed pullies G and K. Under this arrangement the alternate circular movement of the lever A B will produce the alternate rectilinear motion of the portion H of the chain, a reciprocal movement will also be afforded by this machine.

This movement has been successfully applied to a machine for cutting the tops

of piles situated below the surface of the water, and is in practice one of the most simple and effective contrivances for that purpose.

C 17.

This combination of levers in zig-zag arrangement is well known; it is applied in the contrivance of various toys for children. It has been also applied to the construction of a machine for raising sunken vessels, by Du Vivier. See Machines approuvées par l'Académie des Sciences, Vol. vi. No. 429. We also find several applications of the same movement to the construction of various machines in De Besson's work, Théatre des Instruments de Mathématiques, already spoken of; but these are all of them more or less imperfect. This author proposes to communicate the alternate circular movement by a fixed adjusting screw, this is composed of two distinct screws having their respective threads in opposite directions. The screw by its rotation produces the alternate approach and separation of two nuts fixed at the extremities of the two lower or first levers of the zig-zag arrangement. This piece of mechanism is also applicable to many other practical purposes *.

The pincers generally used for lifting or drawing up heavy bodies from the bottom of the sea, is also an application of the same principle.

The common spinning reel is an highly ingenious and useful application of this combination of levers.

In the Annales des Arts et Manufactures, Nos. 19 and 20, we find the description of a pump on a new construction, presented to the Minister of the Marine, by M. Berger.

This is a double piston pump, which seems to embrace advantages deserving attention. A report was made to the Institute on the subject of this pump by Messrs. Borg, Monge, and Lévéque; it is inserted at length in the abovementioned numbers of the Annales des Arts et Manufactures, and merits an attentive perusal. It is here asserted that the idea of this engine did not originate with

* Several applications of this machinery may be found in the first volume of Leupold's "Theatrum Machinarum Generale." Leipsic, 1724.

M. Berger, (and to this M. Berger appears to assent) but that the merit of the invention belongs to Mr. Noble, an Englishman, whose pump on this construction was readily admitted into the British naval service, and was there substituted for the usual chain pumps. It appears that these pumps were first introduced to actual use in the Windsor Castle, a British seventy-four gun ship, in the year 1790, and that their use has been since continued with much benefit to the service. M. Berger proposes two methods for working this pump, one of which however, the reporters reject as impracticable: but they consider the other to be preferable to the crank movement adopted in the English service. The following description of the method they approve is extracted from their report:

" The principal part of the arrangement is a lozenge figured combination of " four iron bars or rods a b, b c, c d, d a, connected at their extremities by hinges " or pin-joints, so that they have free motion on them, and the component pieces " or bars can either extend or close their angles, and arrange themselves in " lozenges of different figure. This combination is represented in the figure as placed in a vertical position, so that one of the diagonals of the lozenge it composes is in an horizontal position, and supported by two bars or pillars a e, c f of equal height, in such a manner that the pin which attaches the contiguous sides of the figure shall also attach those sides to the corresponding supporting pillar. It is evident, that in this position, the other diagonal of the lozenge will be in a vertical position; this must correspond with the centre of the pump barrel and be situated accurately in the prolongation of its axis. To the upper extremity of this diagonal are attached the two rods of the lower piston, and to the other extremity are fixed those of the higher or upper piston; and the same pin which attaches the contiguous bars to that diagonal also attaches them to the piston rods.

It will be understood that, in order to alter the angles which the bars of the figure form with each other, and so extend or reduce the dimensions of the diagonals, the two supporting pillars a e, c f must have liberty of motion. They are therefore set on a cross piece on the joints e, f to which they are attached by a pin, and have thus a movement of rotation in the same plane as that in which the bars of the arrangement are situated.

The construction and disposition of this mechanism being understood, it will appear that by causing the horizontal angles of the figure to approach each other, the upper angle is made to rise, while the lower angle is by the same action, made to descend in the same quantity; and if on the contrary, the horizontal angles of the figure are made to recede from each other or encrease their distance, the upper angle will descend while the lower angle will rise; thus the action of the pistons is produced. It will be seen, that in this arrangement the maximum range of each piston is equal to the side of the figure; the action of the pump does not however require the maximum range of the pistons, nor indeed would it be possible to obtain it in practice; it being necessary for that end that the supporting pillars should vary very little from a vertical position. M. Berger considers the best dimensions for the figure to be about 22. 2 inches in each side, and that 18 inches will allow sufficient range for each of the pistons.

In this action of the pistons it will be understood, that given points in the sides of the figure are elevated and depressed proportionally, so that the range of each piston, and the vertical path of any given point in one of the sides of the figure, are constantly in the ratio of the distance of the point of suspension of the piston, and the point from which it acts, from that centre of motion of the lozenge which is situated at the extremity of the contiguous supporting pillar. The horizontal line which joins the middle of the lower ends, will therefore be elevated or depressed a quantity equal to one-half the range of each piston. M. Berger transmits the action of the moving power directly to an arm placed on this line by the following arrangement:—Each lower piece of the figure is perforated in its middle by an iron axle, to these are fixed two naves of wood of about 3. 75 inches in length, the projecting portion of each axis is cylindrical, and receives a small metal roller having a flanch or projecting shoulder on its outer end; these rollers support a frame which encloses the lozenge, which passes into longitudinal openings made in the side pieces of the frame, and the whole is firmly held together by nuts, as in the modes of fastening practiced in coach building. The length of the openings in the sides of the frame are determined by the range which may be required for the pistons. To the middle of each of these sides is fixed an axis: it is necessary that these should be accurately centred, or placed

accurately opposite to each other, having to perform the office of a single axis passing through the entire width of the frame; these axes pass through the sides of the frame of a set of lever handles which encompass the whole machine, nearly resembling the arrangement of working handles by which the common fire-engine is put in action. The axis of motion of the set of lever handles is supported by two upright pillars C D, the arm which works the lozenge is divided at one-third of its length by the arm of the enclosing frame.

It will be evident that under this arrangement, if the power of men be applied to the bars it will operate to raise or depress the frame, because the flanched rollers passing through the openings in its sides will allow the alternate opening and closing of the lozenge frame, and thus effect the required action of the pistons. It will also be seen that the extent of the motion of the frame will be but one-half that of the pistons, and that the men whose action is directed on the bars, will have to perform a motion through the same space only, as that traversed by the pistons, which will act in a perfectly equal and simultaneous manner, and in the reverse direction. Lastly, the piston rods will preserve the same vertical positions, because those points of the lozenge frame to which they are attached, describe in equal times, two equal and similar curves in vertical planes: these are placed back to back, having their concave sides in opposite direction; those points therefore can only follow the direction of their common tangent, which is vertical.

The statement respecting the range of the pistons being double that of the frame by which they are worked, should not be understood as strictly correct, for in the organization of the engine which we have described, it will become rather greater, from the effect of the rotation of the supporting bars a e, c f, because, by that rotation the horizontal diagonal constantly preserves its horizontal position, during its elevations and depressions; this circumstance is however rather advantageous to the general effect of the engine than otherwise.

In the figure D 17, we have omitted the frame which encloses the lozenge frame, and we have shewn but a small portion of the lever handle g i; upon one side of the portion shewn in the plate, a curved groove n m k is cut, into which the axis n passes, which is fixed to one of the lower sides of the lozenge; and

this axis has a small friction roller upon it, for the purpose of facilitating the motion. This arrangement appears to us to be more simple than that proposed by M. Berger. Notwithstanding the omission of the parts of the original figure above-mentioned, and the other alterations, an attentive reader will find our description perfectly intelligible. Careful reference to the articles A 7, B 7, and K 7 of this work will point out the method of describing the curve required in this instance at n m k.

E 17.

The alternate circular movement of the beam B produces an alternate rectilinear movement for the rods M N and P Q, by means of two portions of chain which are attached to each of the circular curved pieces at the extremities of the beam, and set in contrary directions. The steady motion of the rods M N and P Q is provided for by making them slide through the pieces p, q, r, s.

In Berthelot's work entitled, La Méchanique appliqée aux Arts, vol. i, page 13, we find the description of a mill constructed on this principle. An alternate circular lever motion is converted into an alternate rectilinear motion, by means of two chains which act on two rods, one of which is raised while the other is depressed; each rod carries a click piece which acts on the same side of a ratchet wheel, and so communicates to it a direct circular motion. Upon the axis of the ratchet wheel is fixed the large wheel which drives the lantern pinion of the mill shaft.

In volume i, page 36 of the same work, he applies the same mechanism to a pulverising engine: in this instance the shaft of the ratchet wheel carries fixed projecting pieces which act to raise the pestles or beaters; and in the same volume, we find the same principle applied to raising the hammers of large forges.

Other examples of the application of this contrivance may be seen in the Annales des Arts et des Manufactures, vol. xii, page 83, in a memoir entitled—Description de plusieurs Nouvelles Pompes à Feu, &c. Some interesting observations occur in this memoir respecting the high state of improvement of our steam engines, as relates to the extensive variety of their dimensions and powers; and the consequent facility with which this important auxiliary can be adopted in operations of any given scale. The recent improvements of Woolf, as respects

the economy of fuel may also be seen in the Annales des Arts et des Manufactures, vol. xx, page 294; and in the Bibliothéque Britannique, vol. xxviii, Nos. 221—222.

F 17.

This is an engine or tool familiarly known in the practical arts, under the appellation of Drill, Trepan, or Borer.—A is the spindle or stem; B B the cord or band; C C the cross piece; D the fly; E the socket; F the drill, of which G is the cutting point.

The alternate rectilinear movement of the cross piece C C produces the alternate circular movement of the drill. This method of boring has the peculiar disadvantage of wearing the cutting tool very quickly; and which those boring engines are not subject to which have a direct rotative action, or always in the same direction.

G 17.

A B is a rod or bar, sliding within the pieces n m; the lever D F, turning on its fulcrum or axis E, communicates by means of the arm CD, its alternate circular motion to the bar A B, which has its alternate motion in a right line; a reciprocal action will also take place in this machine. This movement is applicable to pump work. Among the pumps made on this construction, and which merit particular attention, may be mentioned Franklin's double piston pump, a description of which will be found in the Bulletin de la Société d'Encouragement, of the 15th year—August 1816.

H 17.

This figure shews the mechanism used in the double injection steam engine, for the conversion of the alternate rectilinear motion of the inflexible rod of the piston, into the alternate circular motion of the beam, (and reciprocally). The following description of it is given by M. Prony, in the second part of his " Nouvelle Architecture Hydraulique, page 56."

" The parallelogram a b c d attached to the beam by the points a and c " which, with respect to the beam, are fixed points; but the sides of the figure " are at liberty to alter their inclination with respect to each other, by means of " their extremities being jointed together, that is to say, constructed with clips

" or collars, which are fitted on the horizontal axes. (At page 116 of the author's " work, he gives a detailed description of the construction of this mechanism). " The axes in the points a and c are in the same plane with the centre, or axis " of rotation O of the beam.

" Further, the angle d of the parallelogram is constantly retained at a de- " termined distance from the fixed point f′, by means of the metal rod f′ d, " the extremity of which has also a clip or collar which fits upon the centre or " axis passing through the point d.

" This being clearly understood, if we imagine the angle b to be urged or " drawn in a vertical direction, the effort will force the sides b a and b d to " assume an inclined position as in the figure; the points or centres a and c " will describe circular arcs, of which the point O will be the centre, and the " point d will describe a circular arc having f′ d for its radius. But the curves " described by the points a, c, d, being thus fixed and determined, the curve " described by the point b will also be fixed and determined; and it will be " easily seen by inspection of the figure, that when the motion of the beam acts " to drive the point b out of a vertical line in one direction, the effect of the " rotation of d about f′, will be to drive it also out of the vertical line, but in " the opposite direction, and therefore that these counteractions may be so com- " bined and arranged that the curve described by the point b will deviate so " little from a vertical right line, that in practice the difference may safely be " disregarded."

The theory of this parallel motion is also detailed in a lucid and satisfactory manner in the same work, from page 137.

I 17.

A different solution of the same problem has been given by M. de Béttancourt. M. Prony gives the following account of the method, at page 67 of the same work.

Two beams of wood a b, d O have rotatory motion about the points or centres a and O; their extremities b and d are connected by the iron rod b c′ d, having joints at b and d. The lengths a b and d O from centre to centre of the joints,

are equal: the sum of those lengths a b + d O is equal to the distance of the point a from O on an horizontal projection, or measured horizontally, so that, when a b and d O are parallel to each other, or each horizontally situated, a right line passing through d and b will be a vertical line; and since the length of the piece b d from centre to centre of the pins, is equal to the vertical distance of the points a and O, b d takes a vertical position whenever a b and d O become horizontally situated.

By means of this arrangement, if the points b and d do not describe very considerable arcs above and below their horizontal positions, on the levels respectively of the points a and O, the middle point c of the bar b d will have a sensible motion in a vertical right line. In practice it will be found that the elevation or depression of the point b, with respect to the point a, will be more nearly equal to the elevation or depression of d with respect to O, as the motion of the points b and d departs less from their horizontal position; whence it follows that the arcs described by the points b and d, may in such case be considered as equal. This hypothesis being admitted, the points b and d will be always at an equal distance from a vertical line from which the points a and O are also equi-distant; therefore if c′ be placed in the middle of b d, it will be constantly situated in the above-mentioned vertical line. This vertical line coinciding with the common axis of the steam cylinder and its piston rod c′ c, it will only be necessary to attach an horizontal axis to the upper end c′ of the piston rod, which shall turn in a collar formed in the middle point of the bar b d, and the conditions of the problem will be satisfied. A theoretical demonstration may be seen at page 123 of the same work.

K 17.

This figure represents the common Drill-bow—an instrument too familiarly known we presume, to need any particular description.

We shall merely remark that if the alternate rectilinear movement of the drill-bow communicates an alternate circular movement to the spindle, about which the bow-line is wound, it will not be difficult to give it a direct and continuous circular motion; for this purpose it will only be necessary to place a fly-wheel on the spindle, and by a dexterous management of the bow, to make it act on the

cylinder of the spindle in one direction only, and which may be accomplished by a little attentive practice. This contrivance has been applied by M. Raux to give motion to a thread machine, of his invention, and which received the approbation of the Institute, in the year 1806.

L 17.

In this movement, if the wheel A be made to revolve in one direction, the wheel B will revolve in the opposite direction, and they will each act on the corresponding racks of the frame which encompasses them, so as to communicate a rectilinear movement to the bar C D; this movement might consequently also be placed in the seventh range of movements in the table.

M 17.

This arrangement is a modification of the last, and is capable of several highly useful applications.

If two toothed wheels be placed upon an axis, and two racks placed diametrically opposite to each other are made to work with each of them, the alternate circular movement of the axis will communicate an alternate rectilinear movement to the racks, and the extremities of the racks will advance to the axis or recede from it, in a uniform manner. Spinning reels have been constructed on this principle; cylinders of variable diameter might also be thus constructed (see our article C 7.) by properly arranging a sufficient number of wheels and racks.

N 17.

The conversion of an alternate rectilinear motion, into alternate circular. From the Annales des Arts, No. 43.

In the figure, a b c d represents a bar or rod, having its direction of motion confined to a groove; a second bar t v d k v′ t is attached to the first by the joint r, so that the two bars are at liberty to open and shut upon the centre r, similarly to the common folding pocket rule. A plate of metal l n h m, which moves parallel to the line b d, carries the two pins p and q, which are lodged in the hollows, v t′ and v t′ cut in the bar t v d k v′ t.

It will be seen that by this arrangement, if the piece l n h m moves towards the end e of the machine the two jointed bars being supposed to be opened on the joint r, they will be shut by the action of the pin q upon the curve $t' v'$, and afterwards carried forwards by the continuation of the motion of the piece l n h m; and the reverse of this operation will take place, when the movement of this piece is made in the opposite direction. This mechanism has been applied by M. Droz, in the coining press, to the purpose of introducing and shifting the pieces.

The alternate rectilinear movement of this mechanical hand, as it may be termed, is very slow at the extremities of its course, and accelerated towards the middle of it, in order to receive the pieces as they fall from the hopper or feeder of the engine, and to place them under the press without shake, and with perfect steadiness. This movement is communicated to it by means of a pin λ, fixed to the moving plate l n h m, which passes into an oblong aperture formed at the lower extremity of the bar $\delta\gamma\delta$; the axis or pin y stands in an horizontal position, and perpendicular to a plane passing through the axis of the screw of the press; so that when this lever is moved either in one direction or the other, the pin λ is pushed either back or forwards, and consequently the plate l n h m also. The upper extremity of the lever $\delta\gamma\delta$ moves between two metal curves which are described according to given rules, (see our article A 7). Each of these curves is attached by its extremity to the large screw of the press, and are so arranged that the pin λ recedes when the screw is lowered, and reciprocally. From this description the connexion between this piece of mechanism and the press, and the mode of its action, will be understood. The alternate circular movement of the engine being supposed uniform, it will be converted into an alternate circular movement, which shall be slow at the extremities of the oscillation, and accelerated towards the middle of its course, by means of two horizontal curves forming a groove, in which the upper extremity of the vertical lever $\delta\gamma\delta$ will move. The same will take place with respect to the lower end of the lever; in this case, the same extent of oscillation will be preserved if the axis y is placed in the middle of the lever $\delta\gamma\delta$; and will become larger or smaller, as it is shifted nearer to, or farther from the upper end of the lever. This latter irregular alternate cir-

cular motion will be converted into alternate circular of the description required by the nature and intention of the engine.

O 17. Plate 10.

In this figure, A B B represents a side elevation of the beam of a steam engine; G its centre of rotation; n m an iron rod which is at liberty to turn freely about an axis b placed at the extremity A of the beam, and which divides the rod n m into two equal portions; the rod n m is attached by the extremity n to the piston rod f, and at the other extremity m, to the rod p q, which turns on the fixed axis q.

Under this arrangement, we will suppose to be given—1st. The dimensions of the beam of the engine A B B.—2nd. The position of its centre of rotation G. —3rd. The arc b c a which the extremity A of the beam will traverse at each oscillation, and which will be tangential to the direction of the piston f.—4th. The length of the rod n m.

From these data it is required to determine the length of the rod p q, and the position of its centre of rotation q, so as to ensure, as nearly as possible, the rectilinear direction of the piston.

The positions of the three points m, m′, m″, will be determined, so as to indicate the respective situation of the extremity m of the given rod n m, at the commencement—towards the middle—and the close of the oscillation of the beam; and so that in those three positions, the other extremity n shall be situated accurately in the direction of the piston rod f. If a circle be described which shall pass through these three points; its radius will be equal to the required length of the bar p q, and its centre so determined will represent the required centre of rotation q.

The curve described by the extremity n of the piston rod f, will pass through the three points n, n′, n″, and will approximate to a right line, as the arc a c b described by the extremity of the beam, is smaller.

The same course of proceeding will serve to determine (in the figure H 17, plate 9.) the length of the rod f′ d, and the position of the point of rotation f′;

and in the figure I 17 of the same plate, will also serve to determine the length of the beam a b, and the position of the centre of rotation a.

P 17. Plate 11.

In our article G 8, we have given a description of a piece of mechanism in general use in our cotton spinning machinery. In the operations of wool spinning, the motion of the carriage is not uniform through its entire course:—it commences by traversing a space f k with an uniform motion, the distance, this generally extends is from twelve to eighteen inches, according to the quality of the wool; during this interval, the machine thickens a certain quantity of the material, which must be lengthened out to about four feet; the twisting should be encreased in proportion as the thread lengthens, and the motion of the fusees being uniform, the rate of motion of the carriage must be gradually slackened as the thread lengthens. The effective performance of this operation is the result of long practice alone; and our woollen manufactories are yet unprovided with any regular method for the purpose, depending solely on the mechanical dexterity of the operators, who regulate the motion of the carriage with the left-hand, while with the right they produce the uniform rotation of the wheel which gives motion to the fusees. The address required for the due performance of this difficult operation is, as may be conceived, to be acquired only by a course of toilsome and attentive practice which generally occupies a long term of servitude.

These serious disadvantages arising from the misapplication of labour would be completely obviated, as well as a satisfactory general improvement effected, by the general solution of the following problem.

In the mechanism represented at G 8, plate 5, let the rotatory movement of the pulley B be uniform, and let it be required to determine the means of rendering the velocity of its movement of conversion, variable at pleasure.

The following course of proceeding will afford the required solution: A drum A (figure P 17, plate 11.) is substituted for the pulley B of the figure G 8, plate 5; the figure of the drum wheel will be determined by the nature of the velocity of the required conversion. From the extremity a of the drum there projects a neck

having a spiral cut upon it which after a certain number of convolutions, terminates at its other extremity b. Let f h represent the entire course which the carriage will perform, and let h g be taken equal to the height a c of the drum wheel A, let a rope or band be attached to the point f, and a second to the point g ; each of these must be equal in length to the distance f g ; the other extremity of the first band is attached to the point a, and the second to the point b, after being coiled on the spiral in opposite directions. The two cords should be in contact always at the same point of the the drum A.

It will be seen by this arrangement—1. That if the drum A revolves uniformly on its axis, its movement of conversion will vary as the radii of the spiral.—2. That as one of the bands is coiled by the motion of the spiral, the other is uncoiled ; and by this means their tension is constantly preserved.—3. That lastly, the drum A will have no tendency to motion in the direction of its axis a c.

This piece of mechanism was communicated to us by M. Sureda, whom we have already had occasion to mention in our article O 7.

According to a series of observations made by M. Sureda, in the most careful manner for the purpose of determining the ratio of the velocities of the carriage, under the management of the most experienced operators, it appears that at the end of the first part of its course, the carriage had still to traverse a distance of four feet four lines, or 580 lines * ; and which was traversed by it, while the wheel which communicates the uniform motion to the fusee performed ten revolutions : the spaces respectively run through during each revolut ion were as follows :

* It may be necessary, for the information of the general English reader, to note that the French measure of length termed a line, is to the inch as twelve to one ;—580 lines are therefore=four feet and four lines.

	Lines.
During the 1st revolution of the wheel	112
2nd	88
3rd	74
4th....................	62
5th....................	53
6th	46
7th	41
8th....................	38
9th	36
10th	30
Total	580

The first part of its course of one foot and a half, was uniformly traversed in the time occupied during two revolutions of the wheel.

It will readily be conceived that notwithstanding the utmost care and intelligence on the part of the observer, these results may be subject to error; and we do not consider we exceed the probable extent of such errors in stating the following table of results in correction.

	Lines.
During the 1st revolution of the wheel	106
2nd....................	90
3rd....................	76
4th....................	64
5th	54
6th	46
7th	40
8th....................	36
9th	34
10th	34
Total	580

In the figure N, plate XI, let the line c a be divided into nine equal parts, and through the points of division draw the perpendicular lines $\overset{\text{IX}}{y}$, $\overset{\text{VIII}}{y}$, $\overset{\text{VII}}{y}$, $\overset{\text{VI}}{y}$, $\overset{\text{V}}{y}$, $\overset{\text{IV}}{y}$, $\overset{\text{III}}{y}$, $\overset{\text{II}}{y}$, $\overset{\text{I}}{y}$, $\overset{\text{O}}{y}$, which shall be relatively as the tabular numbers of the last stated series, and let a curve b h n m be described through the extremities of these lines. Let y represent the ordinates of this curve, x its abcissæ from the vertex h, p the distance $c c' = c' c''$, &c. which is the measure of separation of the perpendicular lines $\overset{\text{IX}}{y}$, $\overset{\text{VIII}}{y}$, $\overset{\text{VII}}{y}$, &c.—and a the distance h r from the vertex of the curve to the line a c.

The well known equation $y^2 = p^2 (x - a)$ in which $p = c c' = c' c''$, &c. and $a = y' - \frac{1}{4} = 34 - \frac{1}{4} = 33.75$ will agree with the observations, as may be shewn by substituting for x, its values $y' - a$, $y'' - a$, &c.; in which case we obtain successively $y = \frac{p}{2}$; $y = \frac{3}{2} p$, &c. &c.

In practice it may be arranged that the spiral shall make twelve revolutions, the two first for the first part of the course of the carriage, and the remaining ten revolutions for the second part of the course; the whole course of the spiral must be equal to the distance f g.

If the line a c of the figure N be supposed equal to the height of the drum A, and that ϑ represents the ratio of the diameter to the circumference, each term of the last stated series must be multiplied by $\frac{\vartheta}{2}$ and the curve b h n m be drawn; and this will be the generating curve for the surface of the drum.

The drum A will thus be composed of two portions, one a r u of a paraboloidic figure, by which the progress of the carriage will be duly regulated, during the second period of its course; and the other, b r u t, of a cylindrical figure, which will propel it during the first period of its course, with an uniform velocity.

The drum A may be placed in communication with the mover, or be detached from it, at pleasure, by the methods already explained; and thus by a suitable application of such a method, the carriage may be retrograded to the point whence it commenced its course without the necessity of reversing the action of the mover.

SECTION XVIII.

To convert alternate rectilinear motion, of uniform velocity, or which varies by a given law, into alternate motion in a given curve, of velocity similar to that of the original motion, uniform, or variable by a given law, and in the same or in different planes of direction.

THE given alternate rectilinear movement will first be converted into an alternate circular movement by Section XVII, and the movement so obtained into an alternate movement in a given curve, by Section X.

SECTION XIX.

To convert alternate circular motion, of uniform velocity, or the velocity of which varies by a given law, into an alternate circular movement, of velocity similar to that of the original motion, uniform, or variable by a given law, and in the same, or in different planes of direction.

A 19.

ALL the arrangements contained in Section VIII, and a part of those contained in Section IX, will afford solutions of this problem.

B 19. Plate 9.

M. Camus in the Receuil des Machines approuvées par l'Academie, Vol. ii, Nos. 136 and 137, describes some machines of his invention for the purpose of giving motion to several sieves by one operation.

The entire arrangement in the figure may be reduced to a large table A B C D; above the table is placed a plane board E F, supported by two iron axes n, m, which turn on iron upright pieces, fixed to the table. Upon the prolongation of one of the axes n m, or upon an arm s, is fixed the pendulum R S; and the sieves are arranged on the board E F.

The moving power produces the oscillation of the pendulum R S, and consequently also communicates an alternate circular movement to the board E F; at each oscillation the edges of the board strike against the table B C, and very effectively represents the motion usually communicated by hand.

C 19.

In this machine the cord a b c is attached in a to the spring B, and after being coiled about the cylinder A, is afterwards attached to the extremity c of the treadle D. The alternate circular movement of the treadle communicates a movement of the same description to the cylinder A.

D 19.

In this arrangement, the alternate circular movement of the treadle D, produces the direct circular movement of the fly wheel M, and also a second alternate circular movement in the cylinder A.

E 19.

The Nippers of the Sawing Machine.

These nippers are composed of two pieces of iron a b c d, e f g h, which turn upon the centre or axis i; the extremities a b and e f of these pieces are cut in a semi-circular form; the interior edge is serrated, they form together the jaws or head of the nippers. The other extremities b c d and f g h of the same pieces, terminate in two circular arcs d c and g h; the first of them being toothed on its outer or convex edge, the latter on its inner, or concave edge. At the middle point between the interval which separates the two circular arcs d c and g h, an axis C is placed perpendicularly to the plane of the machine; this axis carries two pinions n and m, the first of which, n drives the arc d c, and the second m, the arc g h.

The alternate circular movement of the axis C, operates to open or close the jaws of the nippers at pleasure.

F 19. Plate 10.

A long bar or plank A B, is traversed in its middle by an axis fixed at the

upper end of the upright piece CD. The alternate circular movement communicated to the extremity of A B, by the action of a person seated at that point, and which tends alternately first to elevate it by the sudden action of the feet downwards on the ground on which they are then placed, and afterwards to produce its descent, by the effect of their gravity. These movements are communicated conversely to a person seated at the opposite extremity, whose action similarly exerted, tends continually to encrease the oscillations of the machine.

SECTION XX.

To convert a given alternate circular movement, of uniform velocity, or which is variable by a given law, into an alternate movement in a given curve, of velocity similar to that of the original movement, uniform, or variable by a given law, and in the same, or in different planes of direction.

A 20.

ALL the movements described in Section X, will afford solutions of this problem.

B 20.

This is a turning engine by which screws of any description may be made, without centres. It is the invention of M. Grandjean, of the Royal Academy of Sciences; and is described in the "Machines approuvées par l'Academie," vol. v. 1729, No. 336.

" This engine is composed of a firm supporting frame or stand A B, and two " upright pieces or puppets P Q; these have instead of centre points, two collars " S T, which receive the mandrill F H, whose terminations are conically pointed; " F H carries the piece R which is to be cut, and also the pulley G which re- " ceives the band GO attached to the treadle O. The puppet Q carries an " iron arm I, to which is attached in I a square H K, also of metal, one ex- " tremity of which presses on the point H of F H, and consequently tends to " press it from H towards F. The point F is supported upon a piece E, which " is moveable upon an axis D, at the extremity D of which, the piece D C is

" set upon a square; and in a groove formed in this piece there runs a sliding " piece N to which the band N O is attached, and thence passes to the treadle O.

" This understood, it will be evident that when the foot is applied to the " treadle, it will produce the rotation of F H, and will also lower the piece D C, " that this motion of D C will cause the advance of F H from F towards H in " a quantity which will be always reciprocally proportional to the distances D N " of the sliding piece N from the centre of motion D; and the piece N being " moveable, it may be adjusted or placed in any required situation or distance: " hence it will result that during a revolution the axes will advance whatever " quantity may be required, and consequently if the cutting tool be applied at " R, any required screw may be produced, as was proposed.

" If a spiral or screw be required, the thread of which shall become gradually " closed or finer, it will be only necessary to take off the piece D C and substi- " tute for it the piece D N C, figure 2, the periphery N V C of which is a curve " in which the radii D N, D V, D C encrease as the thread of the screw to be " cut is required to close; thus, each point of the curve, as C, V, N, &c. will " successively perform the office of an arm or lever of different length, continu- " ally substituted for the arm D N, figure 1, which will produce an unequal " retrograde motion of F H towards H, and consequently the thread of the re- " quired screw will be gradated as the radii D C, D V, D N."

C 20.

M. Clairault is the author of a memoir included in those of the Academy of Sciences for 1734, in which he proposes the solution of several important problems.

One of these has for its object the determination of the curve M O N, upon which if the square M C N be moved always in contact, its vertex C shall be always in the given curve E C.

The required movement of the square may be given by an alternate circular movement, which by the solution of the problem will be converted into an alternate movement in the given curve E C.

D 20.

In this plate, the figure on the right represents a front elevation, and the

figure on the left a side elevation of the subject. The same letters of reference are placed as usual to the corresponding parts of the machine in both figures.

These figures represent the machine used for rifling gun barrels, in the Royal Arsenal at Versailles.

A A are two upright timbers placed perpendicularly upon the lower or ground framing B, and the cap piece C C attaches the upper ends of the upright timbers; the whole composes a frame work, the firmness of which is farther secured by the auxiliary pieces D and E.

G is a cylindrical roller on the axis of which is placed the toothed wheel H, and this is driven by the pinion I; the moving power is applied to a winch set on the axis of the pinion.

a b c d is a carriage which slides vertically in the frame A A B C C; two ropes e e are fixed to the upper cross framing of the carriage, they pass over two fixed pullies attached to the cap C, and are afterwards coiled on the roller G; another cord f is attached to the middle of the lower cross framing of the carriage, passes over a fixed pulley to the lower piece B of the principal frame, and then returns; and is coiled also upon the roller G, but in a contrary direction to that of the cords e e.

The carriage carries an iron cylinder g h; the extremity g of which rests upon a block of metal, fixed in the middle of the upper surface of the lower cross piece of the carriage; it passes through an aperture formed in the middle of the upper cross piece, and terminates in h by an auger or other boring tool suited to the operation. The iron cylinder g h carries a pulley m, at a point nearly equidistant from the upper and lower cross pieces of the carriage.

A cord n o p q is fixed to the cap in the point n, passes over the fixed pulley o placed near the middle of one of the vertical or side frames of the carriage, passes entirely round the horizontal pulley m, and afterwards over a vertical pulley p placed opposite to the pulley o in the other side frame of the carriage, and terminates in q, where it sustains the weight N, which operates to keep the cord in an uniform degree of tension.

If the moving power act by an alternate circular movement, that movement

may be converted into an alternate rectilinear movement by the method already explained in our article B 17. The iron cylinder g h will participate in this alternate rectilinear movement of the carriage; and will at the same time have an alternate circular movement produced by the uniform tension of the cord o n p q. The combination of these two movements will therefore communicate a spiral movement to the boring tool, as in the subject exhibited in our article K 10.

SECTION XXI.

To convert an alternate movement in a given curve of uniform velocity, or which is variable by a given law, into an alternate movement in another given curve, of velocity similar to that of the original movement, uniform, or varying by a given law, and in the same or in different planes of direction.

THE given alternate movement in a curve will be converted into a direct circular movement by the methods shewn in Section IX.; and the movement so obtained, into an alternate movement in the curve required by the examples of the same Section.

Those movements which are adapted to the solution of the problems stated in Section XIV, will also apply to this Section.

THE END.

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ALPHABETICAL INDEX.

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ALPHABETICAL INDEX.

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Analytical Essay on the construction of Machines.

Synoptical table of mechanical movements, displaying a Selection of examples, arranged under the classes of rectilinear, circular, & other curvlinear movements, & subdivided into direct & alternate motions, & of uniform or variable velocities.

A single asterisk (*) affixed to the descriptive title of a division, signifies an uniform velocity, or which is variable in a given ratio. — Two asterisks (**) signify the same velocity as the movement from which the conversion is made, direct or variable in a given ratio, & in the same or in different planes. —

			Sec.	A–U
From direct Rectilinear motion (*) to produce......	Rectilin.r motion.	direct (**)	1	A: Convert the recti-lin. motion into circular by Sec. 3, & the exam.s of Sec. 3 will give the req.d exam.s
		alternate (**)	2	Convert the rectilinear motion into circular by the methods shewn in Sec. 3. & the exam. of Sec. 7 may then be applied to this Sec. as well as the fig. A2, & the other mechines described in the body of the work.
	Circular motion.	direct (**)	3	
		alternate (**)	4	A: Convert the rectilin.r motion into circular by Sec. 3. & the exam.s of Sec. 9 will afford the required exam.s.
	Curvlinear motion.	direct (**)	5	Convert the direct rectilinear motion into direct circular by Sec. 3, & the exam.s of Sec. 10 will give the required examples.
		alternate (**)	6	Convert the direct rectilinear motion into direct circular by Sec. 3, & the exam.s of Sec. 11 will give the required examples.
From direct Circular motion (*) to produce......	Rectilin.r motion.	alternate (**)	7	
		alternate (**)	7'	
	Circular motion.	direct (**)	8	
		alternate (**)	9	
		alternate (**)	9'	
	Curvlinear motion.	direct (**)	10	
		alternate (**)	11	Convert the direct circular motion into alternate circular by Sec. 9, & Sec.s 10 & 20 will give examples of the required conversion.
From direct Curvlinear motion (*) to produce......	Rect.r mot.n	alternate (**)	12	Convert the given movement into direct circular motion by Sec. 10, & that motion into alternate rectilinear motion by Sec. 7.
	Circ.r mot.n	alternate (**)	13	Convert the given movement into direct circular motion by Sec. 10, & that motion into alternate circular motion by Sec. 9.
	Circular motion.	direct (**)	14	A: Convert the given motion into direct circular motion by Sec. 10, & that Sec. will furnish examples.
		alternate (**)	15	Convert the given movement into alternate circular by Sec. 13, & that motion into alternate curvlinear motion by Sec. 10.
From alternate Rectilinear motion (*) to produce......	Rect.r mot.n	alternate (**)	16	Convert the alternate rectilinear motion into circular by Sec. 7, & that motion into alternate rectilinear by the same Sec. All the movements of Sec. 1 will also be examples.
	Circular motion.	alternate (**)	17	A: Some of the movements of Sec.s 3 & 7 are examples of this conversion.
	Curvl.r mot.n	alternate (**)	18	Convert the alternate rectilinear movement into alternate circular motion by Sec. 17, & that motion into alternate curvlinear motion by Sec. 10.
From alternate Circular motion (*) to produce......	Circular motion.	alternate (**)	19	A: All the movements of Sec. 8, & some of those of Sec. 9 will give examples.
	Curvlin.r motion.	alternate (**)	20	A: All the movements of Sec. 10 give examples of this conversion.
From alternate Curvlinear mot.n (*) to produce....	Curvl.r mot.n	alternate (**)	21	Convert the alternate curvlinear movement into direct circular by Sec. 10, & that motion into alternate curvlinear by the same Sec. — Sec. 14 will also afford examples.

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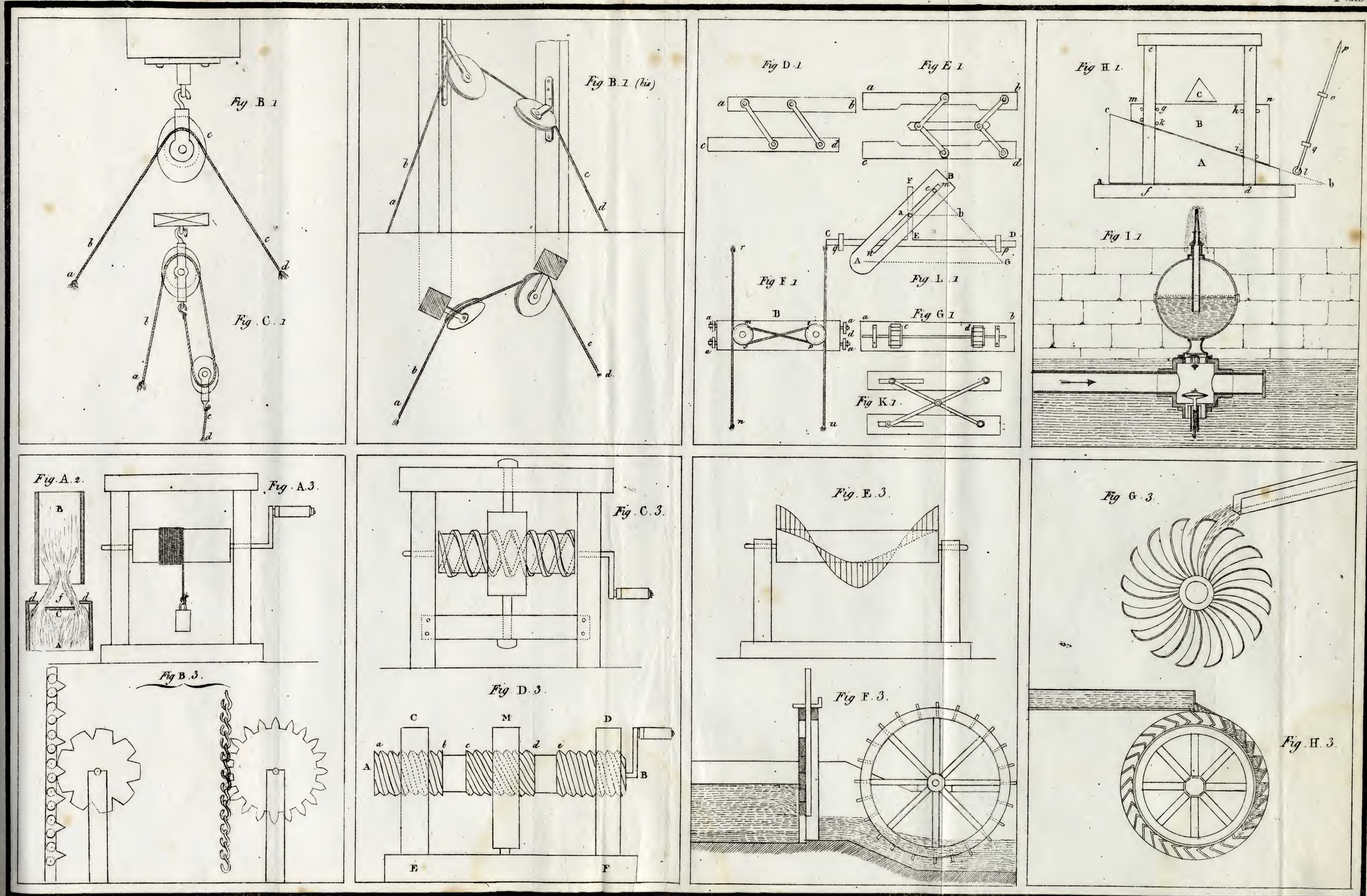
Analytical Essay on the construction of Machines.

Plate 1.



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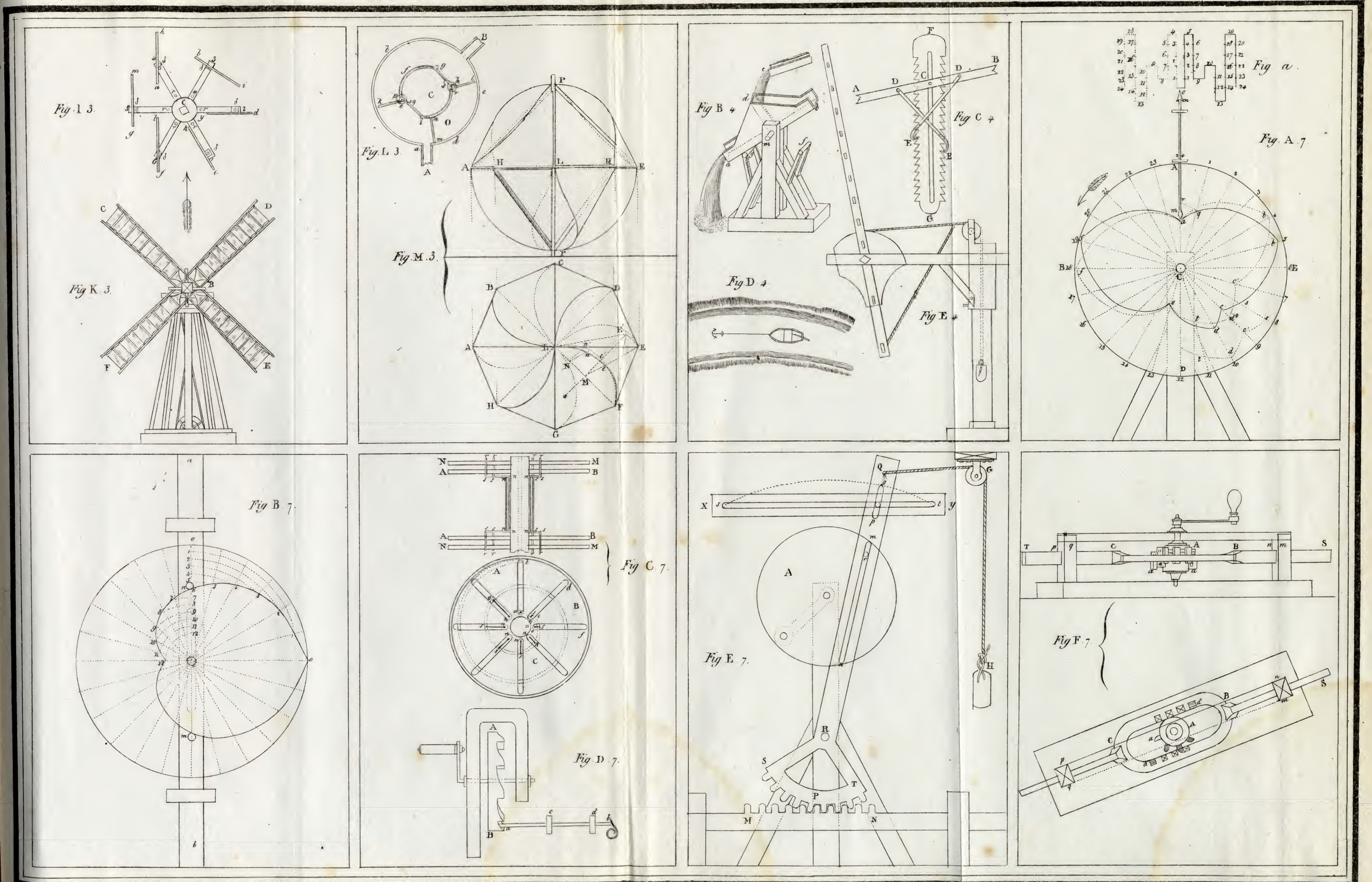
Analytical Essay on the construction of Machines.

Plate. 2.



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Analytical Essay on the construction of Machines.

Plate 3

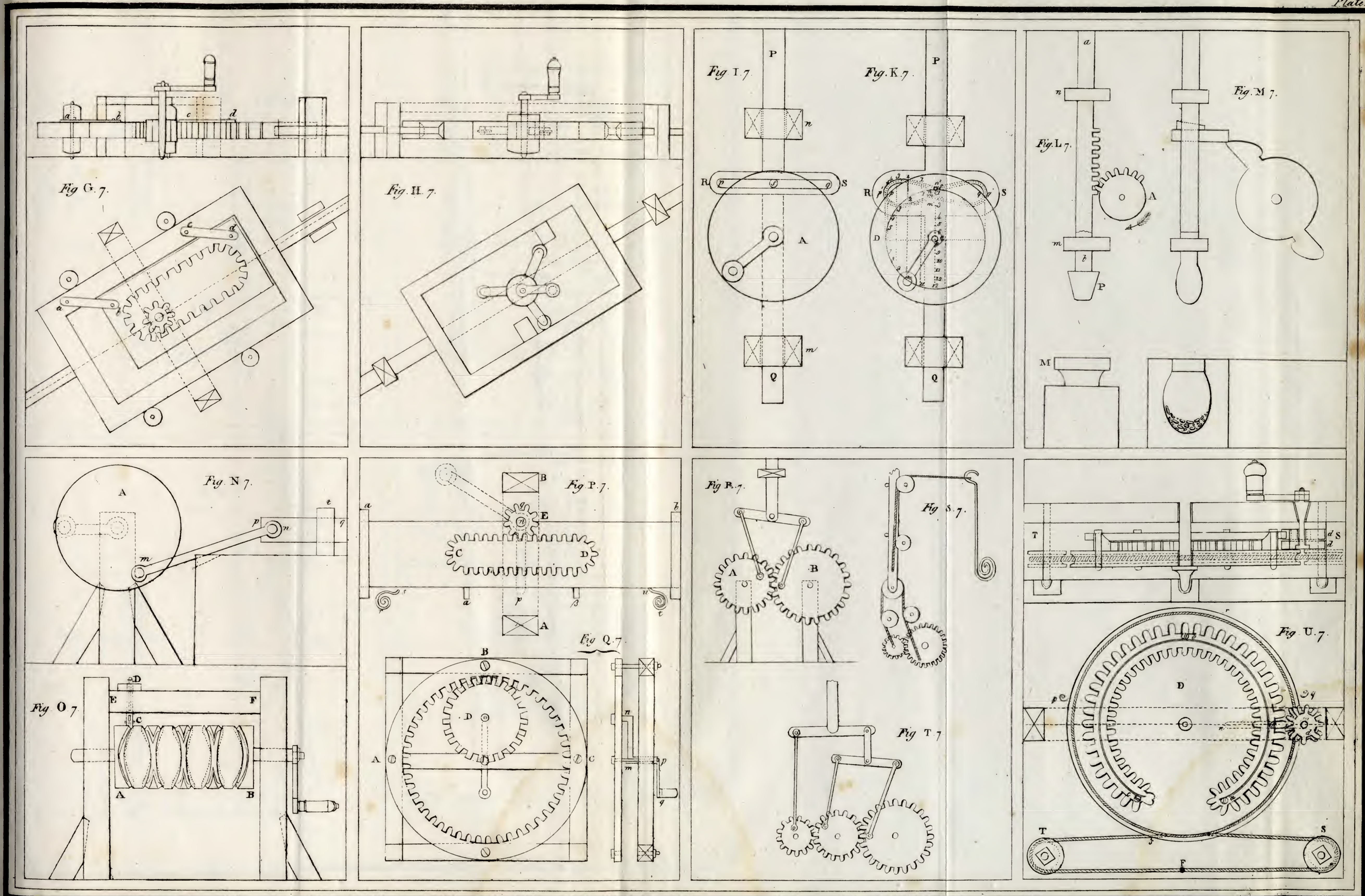

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Plate 4.

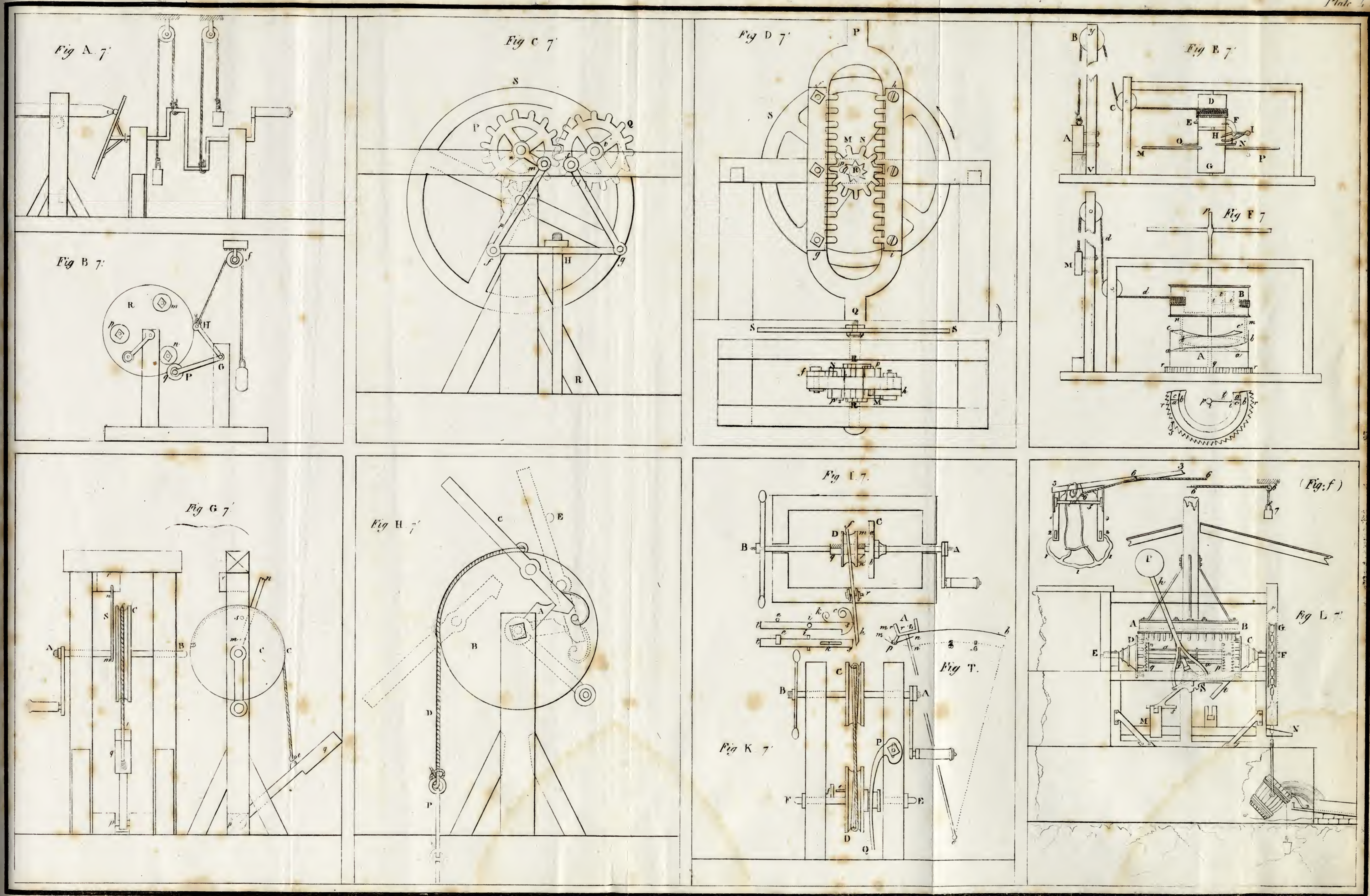

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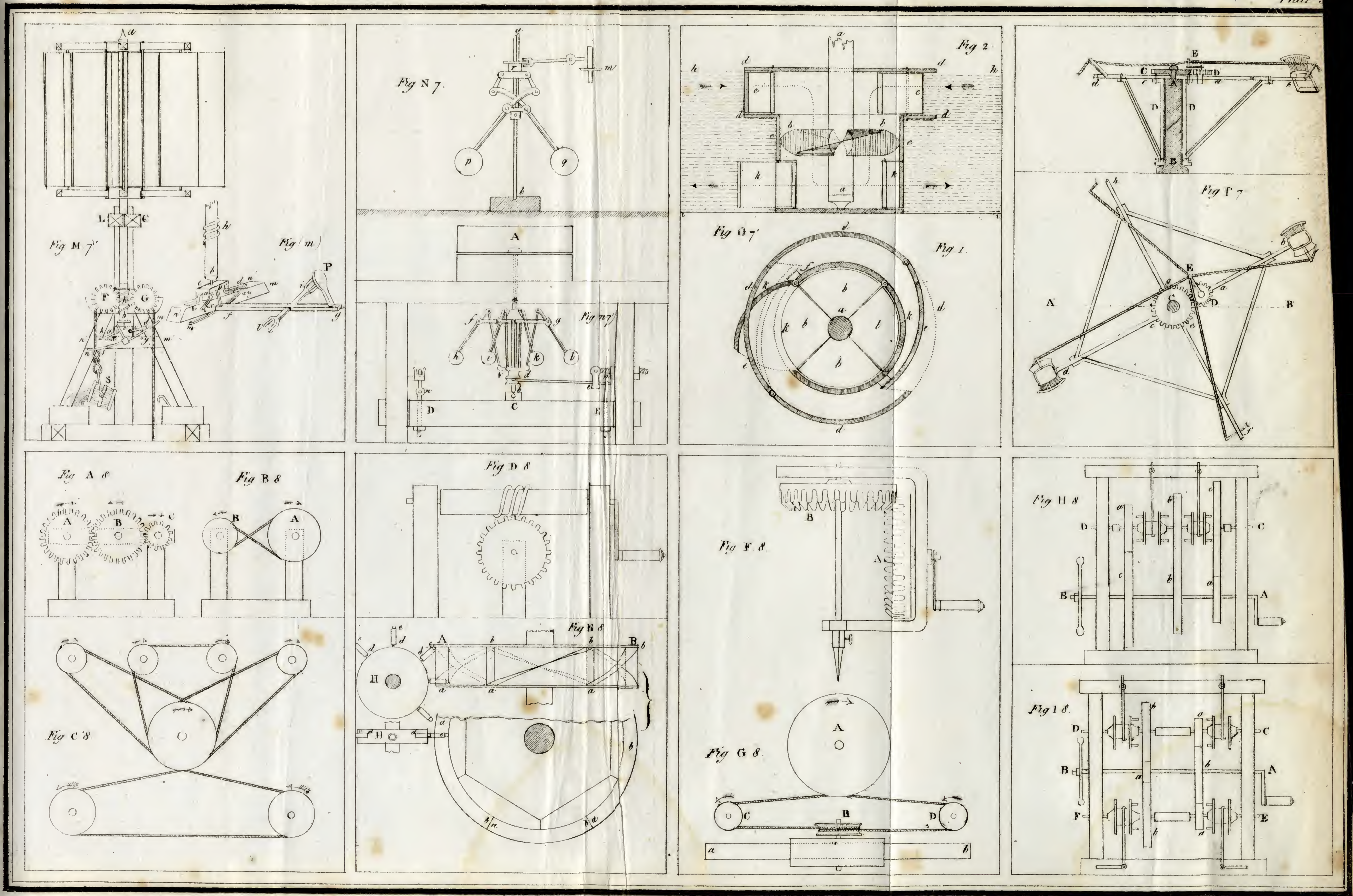
Plate .



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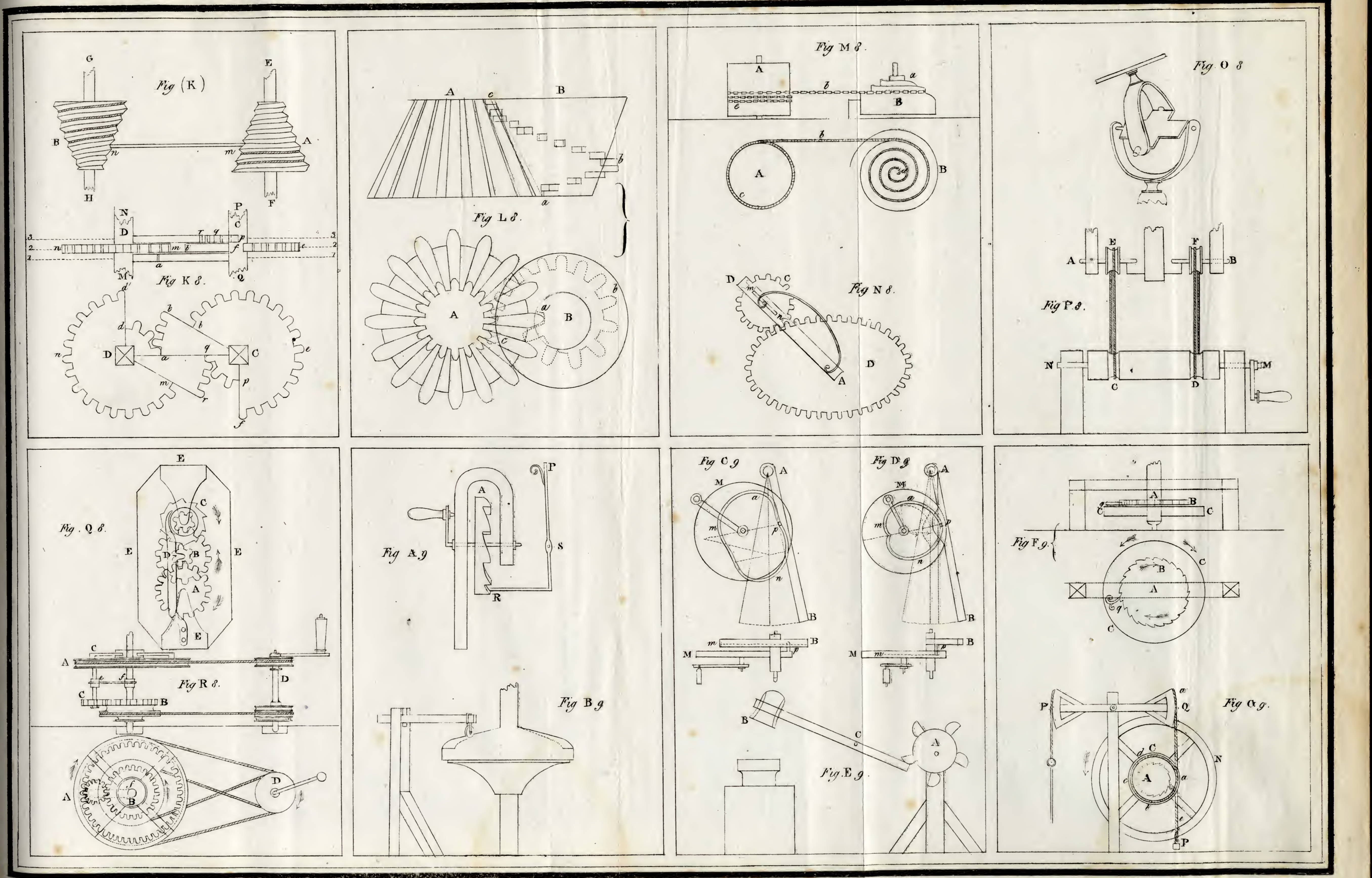

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Plate 7.

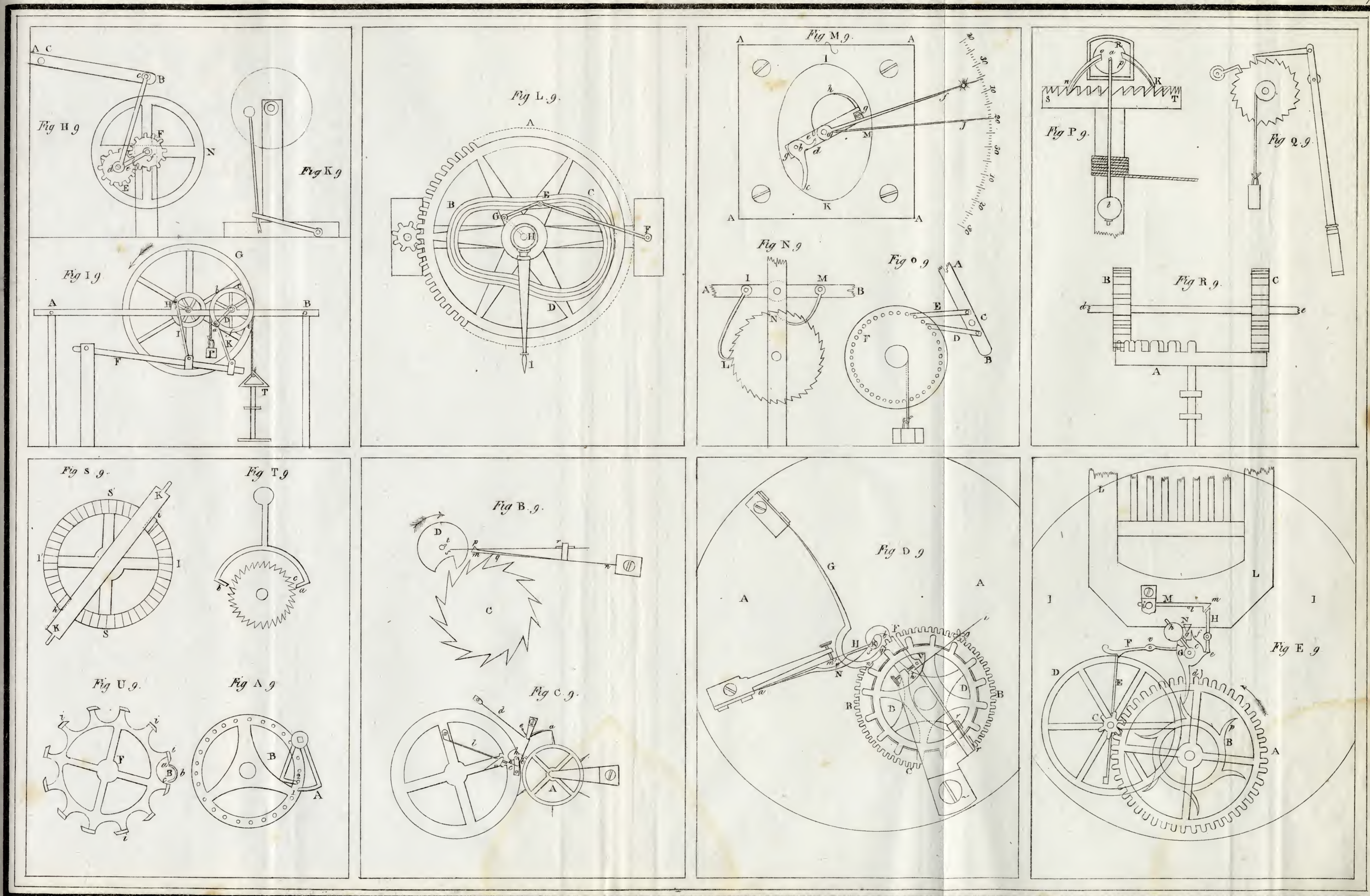

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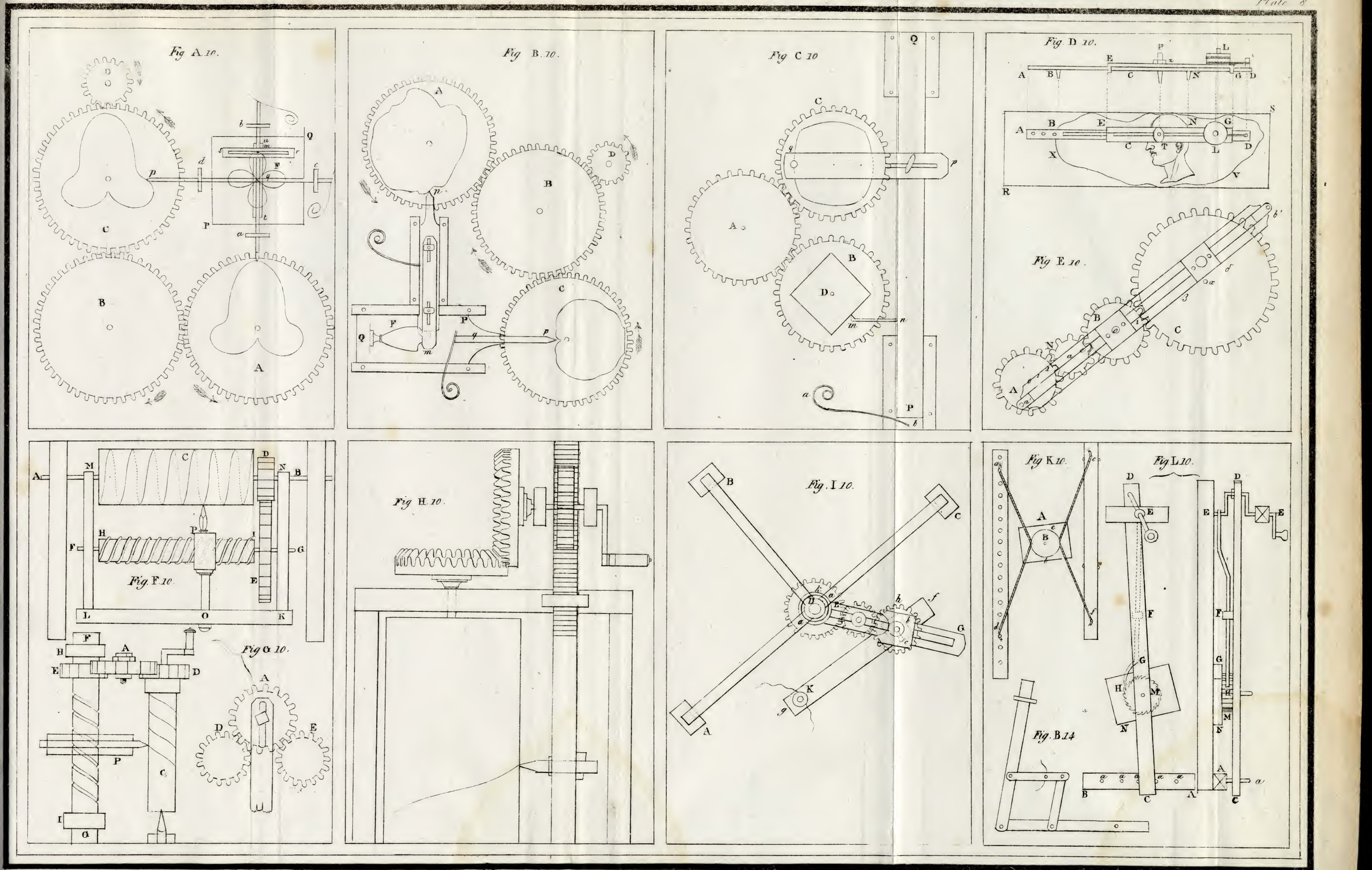
Plate 8



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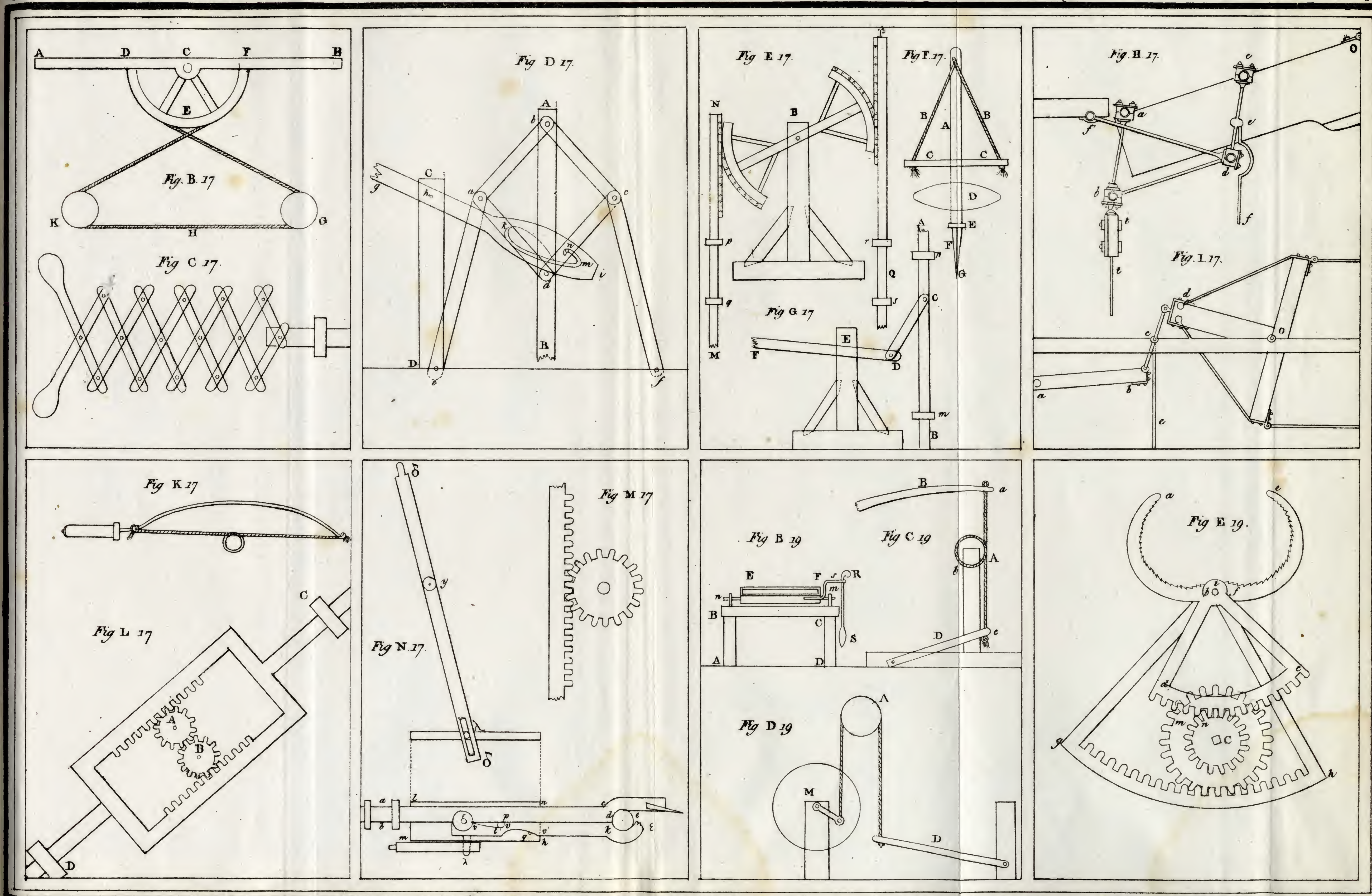

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Plate 10.

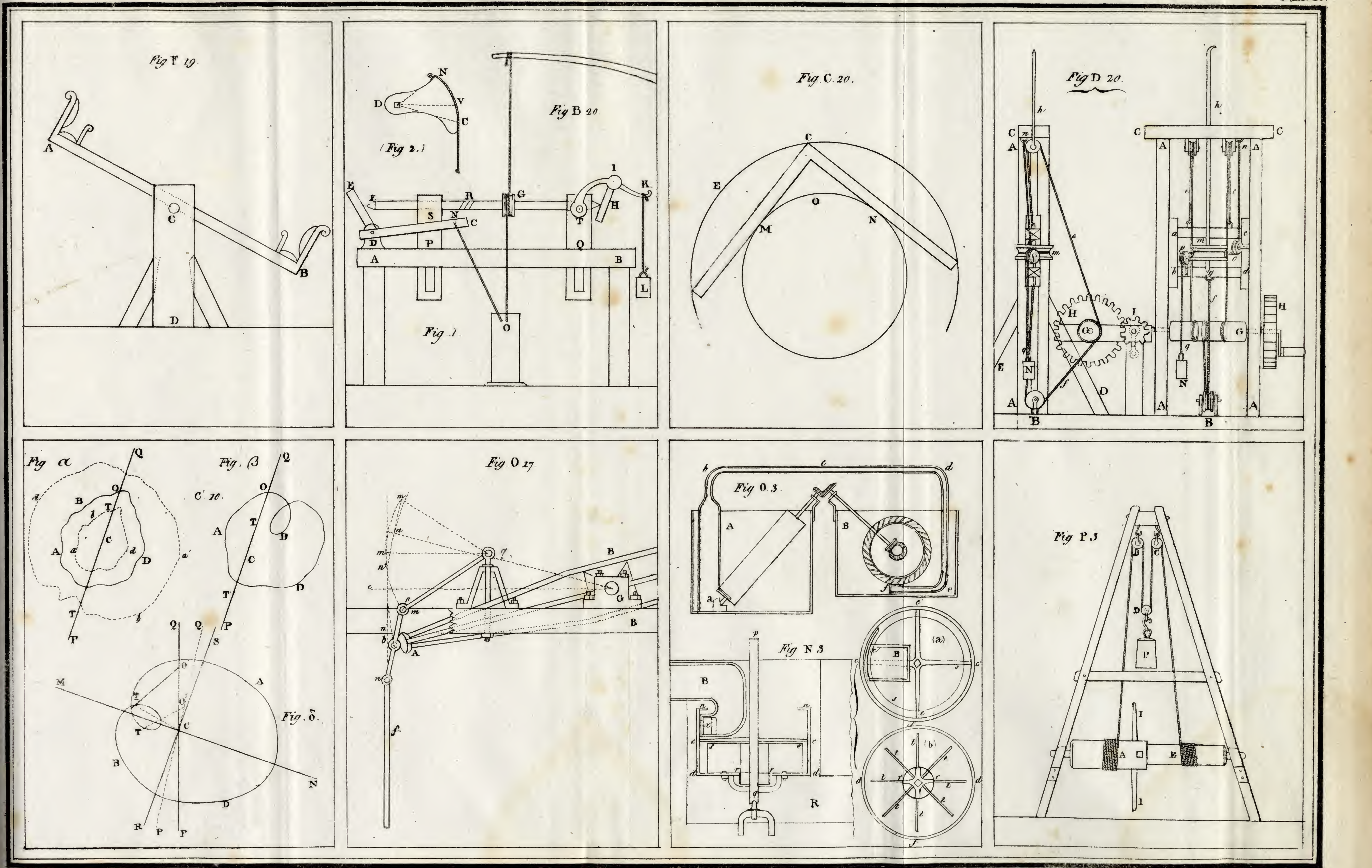

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Plate II.

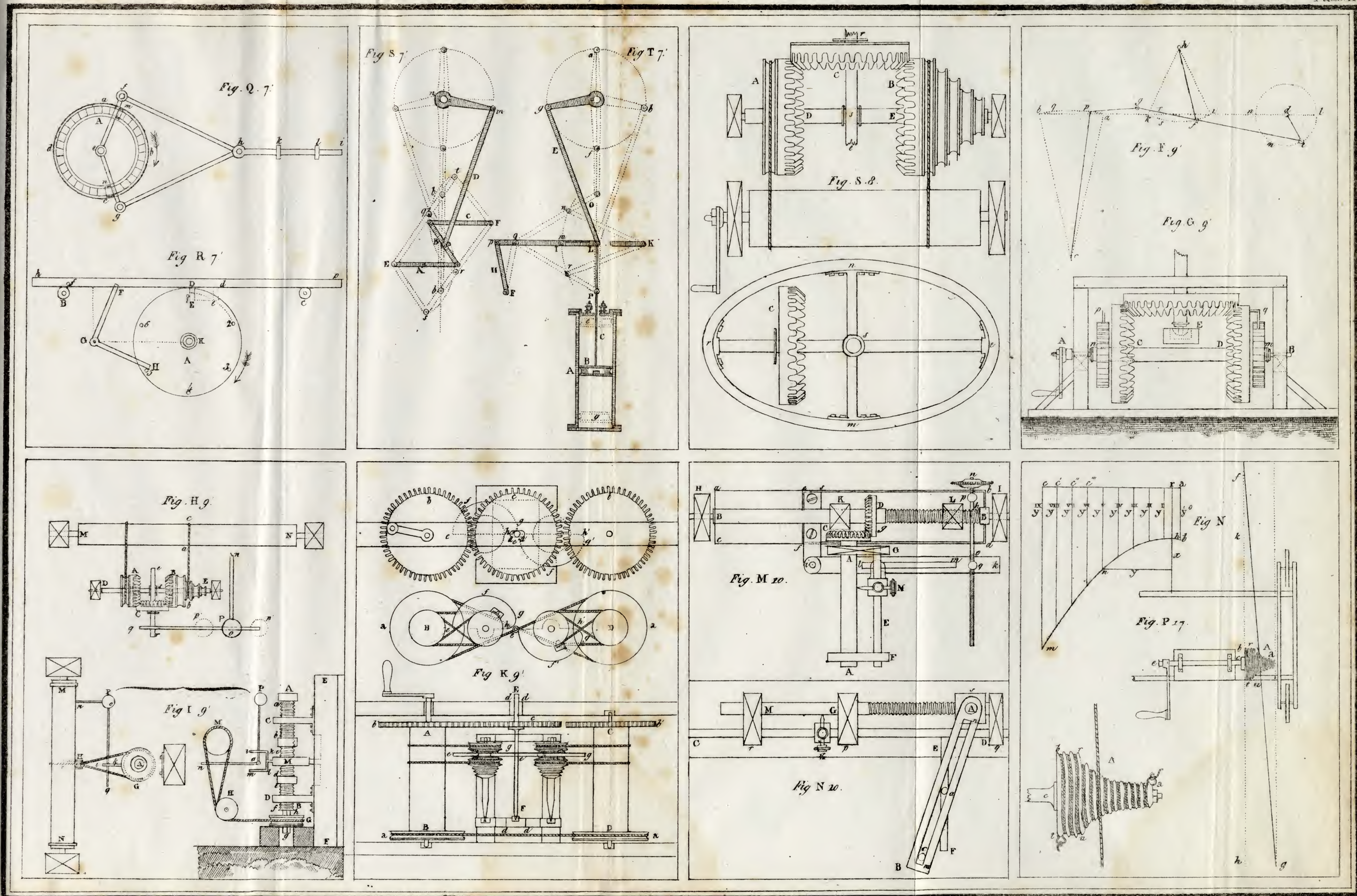

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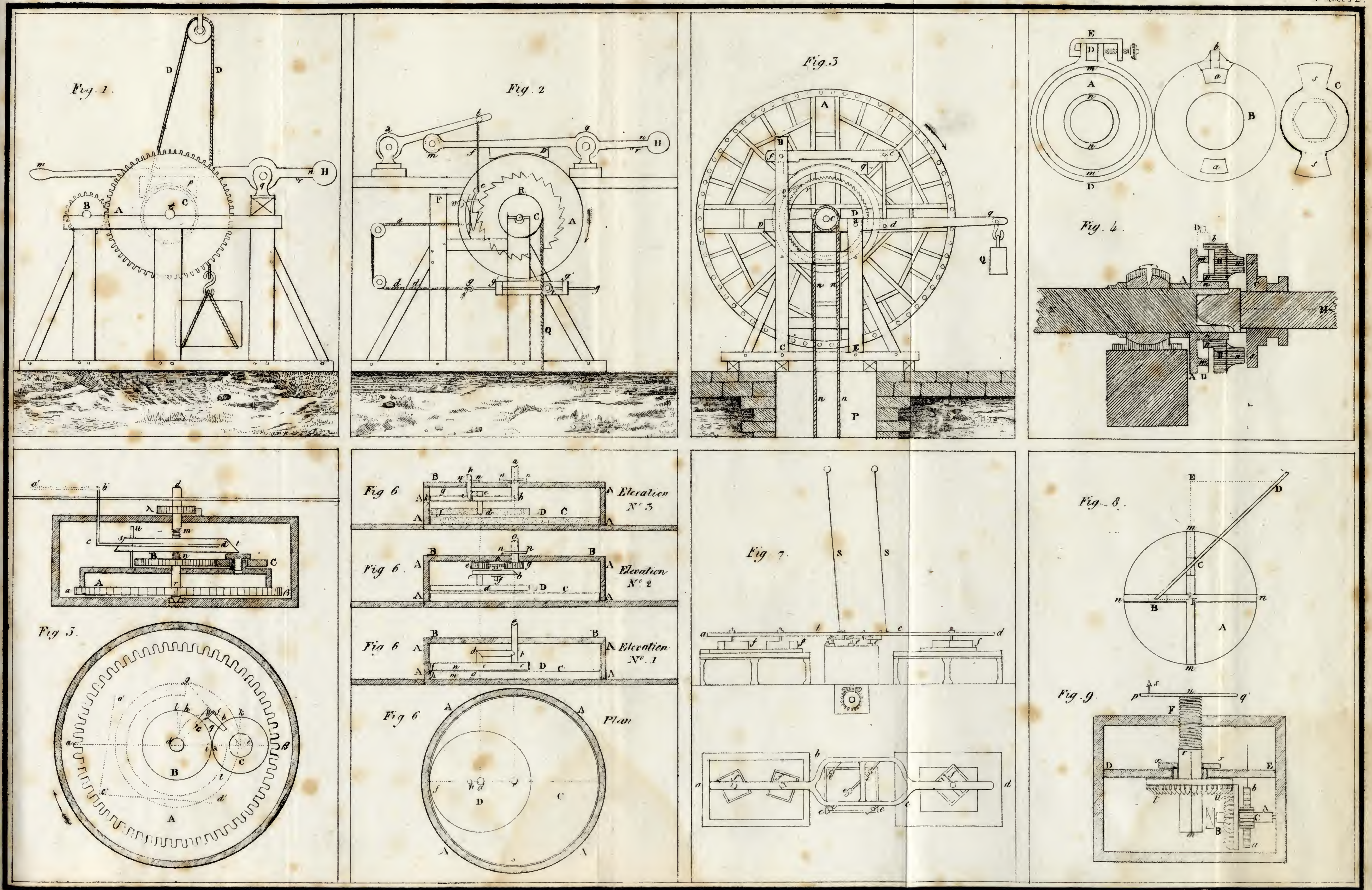
Plate 12.



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